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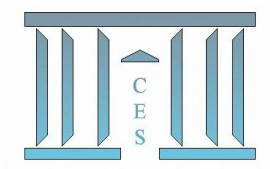

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The debt of the *Hôtel-Dieu* de Paris from 1660 to 1690: a testbed for sovereign default

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The debt of the *Hôtel-Dieu* de Paris from 1660 to 1690: a testbed for sovereign default

Abstract. It is generally accepted that there was no proper evaluation of life annuities in the seventeenth century, thus the bankruptcy of the Paris Hôtel-Dieu 1689 is commonly attributed to this mispricing. New sources show that the prices of annuities from 1668 on are compatible with Deparcieux's mortality table discounted at the legal rate of interest. The bankruptcy resulted from incorrect provisioning of life annuities liabilities rather than mispricing. That story would have been anecdotal if the French king had not decided to borrow using contingent annuities around the same time: the Crown's plan can be shown to be unsustainable.

Keywords: life annuities, financial revolution, early modern Europe, hospitality.

JEL Codes: G22, N13, N23, N43.

North and Weingast (1989) have shown that England won the wars against France not just on the battlefield: the superiority of British *institutions* enabled larger and steadier borrowing to fund a long-term conflict, which ended only in 1815 when Bonaparte was ultimately defeated. Recent studies into this topic have shown that the French tried to compensate the low return on taxation by *superior design* of their borrowing schemes (Beguin (2012) ch. 6 and 7), especially life-contingent schemes such as *tontines* (Gallais-Hamonno and Berthon (2008)). Such claims, frequent among the projectors of the time, might now appear delusory, as it is well known that during the seventeenth century life contingent annuities were priced correctly neither in France nor in Britain (Rothschild 2003). Clark (1999) harshly commented: "The life insurance businesses of the early eighteenth century have been portrayed most generously as mistaken attempts to take the practice of insurance into uncharted demographic territory without the guidance of mortality statistics or actuarial calculation. Most usually they have simply been dismissed as gambling schemes heedless of mortality data and the long-term economics of their operations or, even worse, been condemned as outright fraud." Although there are not much examples of such business in France, an *edict* of the king Louis XIV (1690) forbade the "*Hôpital général* and others to take annuities". This text strongly attacked the method of "taking money without payback option, in order to constitute [life] annuities at rate higher than usual", since it is "from day to day so detrimental as to put [the hospitals] out of order if it were continued for a while." To make a long story short, the edict argues that the issuance of life annuities had led the *Hôtel-Dieu* to bankruptcy. Most historians since that time took it for granted that the Sun King was right and while the *Hôtel-Dieu* itself has been under close review by Fosseyeux (1912), Depauw (1999) and McHugh (2007), there is no detailed account of the financial process described in the aforementioned *edict*.

The case provided by the Paris Hospitals might appear anecdotal in comparison with the far-reaching perspective of North and Weingast. There is nevertheless something worth looking into the details: the French monarchy had begun issuing life-contingent annuities on the very same year when the *Hôtel-Dieu* experienced financial distress. One must then ask at least whether the borrowing scheme of the French Crown can be compared to the *Hôtel-Dieu* experience, in order to assess the sustainability of the former from the natural experiment of the latter. There was no data to perform such comparison so far, but we collected evidence from the notarial deeds and deliberations of the board of the hospital to document its pricing policy and compare it to the series of sovereign borrowing rates contained in Béguin (2012). The data undoubtedly show that the life annuities were correctly (i. e. more than actuarially) priced and that a crowding out effect occurred between the sovereign perpetuities and the *Hôtel-Dieu* annuities. Hence the comparison was unavoidable, and a conclusion could be drawn on the *ex ante* sustainability of the debt issued from 1689 by the Crown.
The rest of the paper is organised as follows: after a presentation of the context and the data (1.), we will prove that the selling price of the *Hôtel-Dieu* life annuities was more than their actuarial value (2.). We will then try to discover the causes of the

1689 bankruptcy (3.) and compare the *Hôtel-Dieu* life annuities with other financial assets available to the French households in the period (4.) to assess the sustainability of the king's borrowing strategy.

*

1. The *Hôtel-Dieu de Paris*: medieval hospital or early financial institution?

After being founded in 651 by Landry, bishop of Paris, the *Hôtel-Dieu* was given written constitutions in 1168 (Imbert 1996). As a result, the cathedral chapter of the diocese of Paris administered every aspect of the hospital, which relied on real estate donations to fund three main missions: heal the sick, house the old, relieve the poor. When, at the end of the fifteenth century, the cathedral canons were stuck into a decade-lasting financial crisis, they asked both the City and the Parlement of Paris for help (Imbert 1993). The laymen took over the administrative management of the hospital and the religious lost their grip on the institution: in the new statutes of 1505, the religious retained authority solely on religious matters, while the board of the hospital featured only laymen, with the *premier president* of the Parlement of Paris acting as chairman. During the next century, the history of the institution matched the narrative of how hospital management became an important matter for the (catholic) urban elites during the Counter-Reformation (1.1.). In this context, life annuities do not appear as a common financing means for charitable institutions, but these sales were framed as charity (1.2.), life annuities have traditionally been used to fund cities in time of distress (1.3.). In contrast with other early implementations of life annuities, the *Hôtel-Dieu* provides valuable data (1.4.).

1.1. Seventeenth-century charity

Historical research on the immediate impact of the catholic Counter-Reformation in France has shown how religious congregations[2] as well as companies of secular priests[3] developed a new spirituality, attracting vocations (in a pre-malthusian context where matrimonial strategies of the elites aimed at concentrating wealth, Béguin 2015) and preaching *active charity*. The founding of charitable institutions is a conspicuous effect of this dynamics, which has been studied from the point of view of hospitals (Barry-Jones 1991, Brockliss-Jones 1997). What Cavallo writes about Torino might be true about Paris as well:

> "Evidently, the institutionalisation [*i. e.* placing them in institutions] of the poor by creating an arena in which city elites could put their prestige on display through their charitable acts stimulated their generosity considerably. In fact, the end of the century is marked by a large increase both in the number of legacies and in their average size." (Cavallo 1995 p. 100)

[2] Such as Feuillantines, Filles de la Charité, Missionnaires Lazaristes, etc.
[3] Such as Berulle's *Oratoire de Jésus* or Ollier's *Société de Saint-Sulpice*.

The only difference between Paris and Torino seems to be in the timing: Cavallo's study begins during the Council of Trent, while the French became impassioned for large-scale charity more than 50 years later, with the foundation of the *Hôpital des Incurables* (1630) and of the *Hôpital Général* (1655). In that time, the *Hôtel-Dieu* already enjoyed a thousand year history, it joined the reformation led in France by *Monsieur Vincent* (de Paul). McHugh's (2007) recent book has a full chapter on "The Reform of the Paris *Hôtel-Dieu*", showing the commitment of the elite manage *and fund* this hospital from the 1650's on. By "elite", we mean that the governors were chosen among the top judges and lawyers with the supreme courts as well as *échevins* and bourgeois of the municipality. After the 1690 bankruptcy, the constitutions were further changed, and the traditional patronage of the *Premier President* was supplemented by highest officials such as the *Premier President* of the *Cour des Aides* and the *Lieutenant de Police*. The donors were no less famous than the administrators, with both the most ancient nobility and the new wealthy *robins*[4].

Many figures were both administrators and donators, such as for instance Jean Bachelier and François Choart. A squire, the former is well into the king's businesses as a *conseiller du roi* and director with the *compagnie des Indes Orientales*; his wills offered 50,000 livres to the hospital. The latter served as *maître ordinaire en la chambre des comptes* and eventually donated 80,000 livres. Both took part in the two weekly meetings of the board, examining up to forty questions per session. While the highest-ranking presidents did not attend more than twice a year, the 8 other members of the board really took care of the *poor diseased*: they did not just watch the expenses, they visited every working part of the hospital down to the kitchen and looked after the constitutions. Perhaps the most spectacular result of their administration was the medicalization of the *Hôtel-Dieu*: between 1630 and 1660, the only physician was supplemented with six more colleagues; moreover in 1636 these doctors were given the right to excuse patients from fasting during Lent.

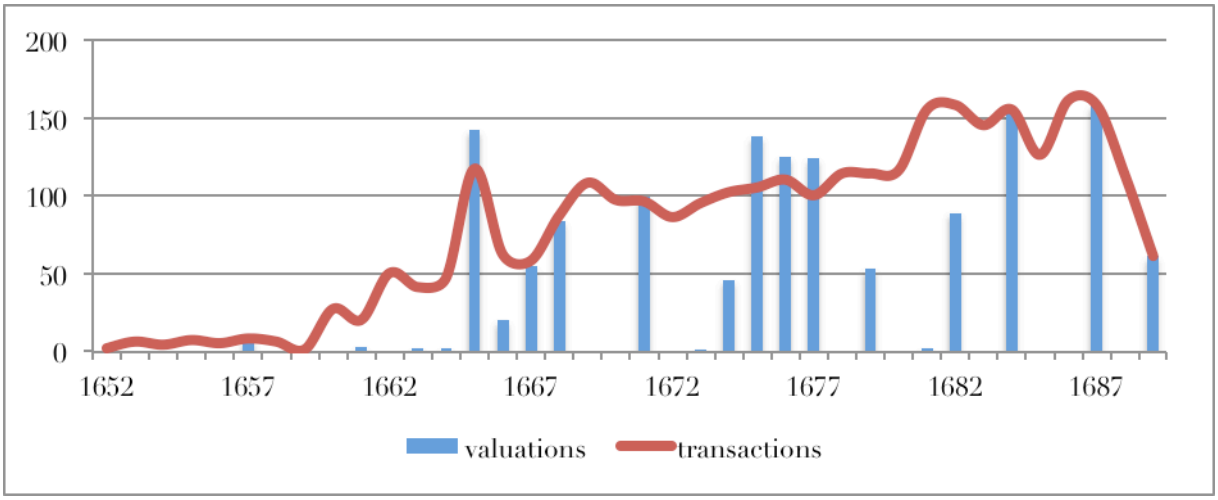
Shifting power from the clerics to physicians is a strong symbol: this is in sharp contrast with the received view that, before the French Revolution, the religious hospitals were not institutions thought to cure but to separate the poor. The reform of the *Hôtel-Dieu* can be thought of as a rationalization in the sense proposed by Max Weber in his *Protestant Ethic*: financial computation is a common practice for the administrators. Although they were devout catholic, likely to be linked with the *Compagnie du Saint-Sacrement*, they had a modernizing view: the "nobility of the robe" (judges and lawyers) used hospital management as a way to display its expertise in social affairs above the traditional "nobility of the sword". The new elite had a distinctive edge in financial management, which proved useful in a time of troubles. During the winter of 1662, for instance, which proved so harsh that

[4] While the duchess de Miramion donated her hotel, which still hosts the *assistance publique* museum, we found records of donations of the duke de La Rochefoucauld, duke d'Estrées and duchess of Nemours during the 1680's alone. Among the junior fellows, two sisters of Colbert during the 1660's: Margueritte, whose husband Vincent Hotman donated his whole wealth, and Antoinette bought annuities for 60,000 livres. Some Colbert hirelings, such as Jacques Chertemps de Seuil "donated" more than 50,000 livres in 1673 alone.

hundreds of poor came to the city to beg for bread, the *Hôtel-Dieu* provided more than two thousands of them with it. As a consequence, the deficit for years 1662 and 1663 overall was running above 225,000 *livres*, almost two thirds of a 360,000 *livres* income. Most of this income came from rent on land donated since the Middle Ages, and was thus inelastic.

The administrators had then to find money in order to avoid bankruptcy. For McHugh (2007) p. 79 "the evidence for how the *Hôtel-Dieu* overcame its deficit is scanty, but it seems that the appeal for more charity, coupled with the temporary cessation of payment to those holding rentes (…) was enough." We know by indirect evidence, that the institution was considered a landmark in financial management, as other religious communities were following its investment advices[5]. But the administrators kept their best trick for the *Hôtel-Dieu* alone[6]: life annuities. While only one such contract was concluded in 1659 and 20 in 1661, the figure was 50 in 1662 and 117 in 1665 (see figure 1 below). During this latter year, the total proceeds of annuities sales was more than 600,000 livres, almost twice the yearly budget of the entire year 1663! At the same moment, while it might appear that the old hospital was evolving into a financial institution, we would like to insist, in full agreement with McHugh, that the sale of life annuities was *framed as charity*.

Figure 1 life annuities valuations and transactions



1.2. Framing issues

It should be made clear that our *framing* of, say, "the sale of life annuities" would have been irrelevant at the time of the story. Buyers were called "donators" and they thought they were *donating* to the *Hôtel-Dieu*: since the Middle Ages, people

[5] During the 1670's we found evidence of three convents buying assets through the *Hôtel-Dieu* notary, Chuppin, himself a member of the board: namely, the Maurists from Saint-Père-en-Vallée, the Missions étrangères, and the nuns at the Madeleine; see MC XXXIII, 124 and 129.

[6] The brothers of charity attempted to share the privilege of life annuities issuance in 1665, but the administrators of the *Hôtel-Dieu* circumvented the project; see *proceedings*, 3rd of June 1667.

have donated real estate to the hospital, while keeping the usufruct during their lives. The same could be done on a basis which seems to us "purely financial": people gave a perpetuity security, such as *rentes sur l'Hôtel de Ville de Paris* which were issued to fund the Crown (Béguin 2012) and kept the income while they were alive. To the contemporaries, though, the framing was not "purely financial" as the perpetuities enjoyed the same legal status as realty (hence the need for a notary to process the sale as if it were land). People literally buying an annuity were in fact buying a perpetuity considered as a realty, which they donated to the *Hôtel-Dieu* while keeping usufruct for life. While this legal and psychological construction seems pretty complex, the administrators were very circumspect to prevent abuse.

The "abuse" which could arise from life annuity buying was not connected with adverse selection in the modern sense, but with alienation of family wealth. Any individual was only made a steward of the lineage's wealth, he could not dispose of it (see infra repayment *to the family*, not the individual). Hence, on the 19th of June 1665, the board does not accept a man's offer "because he looks for an annuity for himself while his wife could survive him and chiefly because he has children…" The very same 1665 year, the administrator discovered that "the wife of Louet de Chatillon" donated three times to the Hôtel-Dieu "while she has children from a first marriage"; they decided to inquire before refunding the money "to the family". Any contract after 1665 would include a clause "if the donator were to marry and were children to advent, the administrators would be free to refund *the family* [emphasis added] with 1/30 interest from today, any further arrear being subtracted[7]". It seems that the Hôtel-Dieu never gave any refund: this clause might have be added to comply with the King's policy, as expressed in an edict of 1661[8].

So far, even during the *Fronde*, when land rents were not paid on time, sometimes not at all, and state securities, which should have provided almost 50,000 livres a year[9], also suffered default, the *Hôtel-Dieu* managed to gather enough donations to overcome the troubles. Then came the year 1662 : the administrators could have played down their role; they decided instead to feed the poor. To fund this ambitious social program, they did what Northern European cities had done before in order to attract funding in times of distress.

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[7] Annuity for Jeanne-Françoise Héron, April the 1st, 1690, AN MC xxxiii, 140. Many other examples, *passim in MC xxxiii*.

[8] Before the 1690 Edict, a previous text in 1661 castigated "**those who had been stripped of all feeling of affection for their parents and families**, considering only their own satisfaction, and seeking only the ease and convenience of life, which they believe to be guaranteed enjoyment of whatever their property that could produce. Those have taken the trouble to increase their income at the expense of **loss and alienation of their funds and principal**. In this thought, some have sold the property of their houses, land and inheritance, and converted the value of these in hard cash: they found people willing to receive and accept as irrevocable donations these monies in exchange for an **annuity during their lives only**, but of greater amount than permited by the law [emphasis added]" See Béguin Pradier 2014 for further detail.

[9] This is one sixth of the yearly income, see *Estat au vray des revenus et dépenses* (AN K1024), which means "truthful statement of income and expenses".

1.3. Life annuities

In continuation of the medieval practice surveyed by Munro (2003), issuance of life annuities during the modern era seems to be connected with the urgent need for money (Hebrard (2005), Béguin-Pradier (2014)): the borrower does concede an interest premium in order to "squeeze the money out[10]" from the speculators. Usually, life annuities are offered at one half of the price for the perpetuities, stated in years' purchase: for instance, when the *taux du roy* (maximum legal rate) was 20 years purchase (100:20=5%) for perpetuities since 1665, this would entail a 10% *nominal* interest rate on life annuities (which was the case from 1702 on with the French *Rentes sur l'Hôtel de Ville*). Of course, the contingent yield to maturity has to be computed taking into account the age of the annuitant and the remaining mortality table.

In 1671, de Witt wanted to inquire into the practice of half-pricing the life annuities. To do so, he computed the present value of expected future payments (given assumptions on mortality as experience did not provide a table before Halley in 1693). The result, for a 4% perpetuity rate (25 years' purchase) was that the life annuities rate should be priced at 16 years' purchase (6.25% nominal rate), instead of the usual halving at 12.5 years purchase (or 8%). De Witt (1671) thus demonstrated that the traditional half-pricing was too generous for the buyer.

But de Witt goes beyond the pricing issue. The reason why he did not give a full price table for the life annuities is simply that he was fully aware of the *adverse selection* caused by a flat rate:

> "the said life annuities are oftenest purchased and sunk upon the lives of young and healthy children of 3, 4, 5, 6, 7, 8, 9, 10 years, or thereabouts. During that time, and for some years ensuing, these young lives, having become more robust, are less subject to mortality than about 50 years afterwards, and than for some years anterior to these 50 years; and so much the more, as during the first aforesaid years they either are not, or are but little, exposed to external accidents and extraordinary causes of death, such as those from war, dangerous voyages, debauch, or excess of drink, of the sex, and other dangers" (de Witt 1671 p. 15)

De Witt here explains how buyers place life annuities on heads with the longest life expectation, hence the smallest risk of death. It is significant that the author does not cite illness as a cause of mortality, while mentioning 'debauch', which did not appear to kill as many people as smallpox (for instance) during that time. It is then obvious that, by choosing children of 10, not 2, investors are seeking to escape the "childhood diseases" which were more or less synonymous with smallpox (measles

[10] "Faire rentrer l'argent", as wrote an employee of the *Contrôle Général* in 1688 or 1689 (during the war of the League of Augsburg, hence), see AN, G7, 1593, mémoires, 4 p.

etc. were not clearly distinguished until the nineteenth century and the generalization of vaccination). By choosing the youngest heads who cleared diseases, investors seemed well aware of their advantage. Hup (2011) has shown that, between 1662 and 1713 in the Low Countries, only 20% of the life annuities were bought by people who thus "insured their lives" (against the possibility of not being able to earn themselves a living); the remaining 80% were sunk on the heads of young children to maximize the duration of annuity and thus, the expected return.

From the Middle Ages on, there have been attempts at controlling adverse selection, but our knowledge so far is limited. Van Schaïk (2003) recalls that some cities set up age limit: 40 years (Augsburg 1457), 60 years (Nurnberg). Gilomen alludes to prices negatively correlated with age of the annuitants: from 5 to 7 years purchase in Southern Germany in 1373 (Gilomen 1984 p. 129), from 10 to 14 years purchase in Switzerland during the fourteenth century (Gilomen 2003 p. 136). Jack (1912) gives earlier examples, 4 to 10 years purchase in Breslau between 1342 and 1379, among others, but this instances, although they have been copied by Murphy (1939) and then Poterba (2005), come from Stobbe (1865) and have never been checked since then. To sum it up, we know that people knew, but this is not enough to believe that they did well to counter adverse selection (Pradier 2011). More precisely, before 1672 we had no mention of annuities sold at price varying with age. Hôtel-Dieu had a clear age-price table before that date, and before de Witt.

1.4. The data

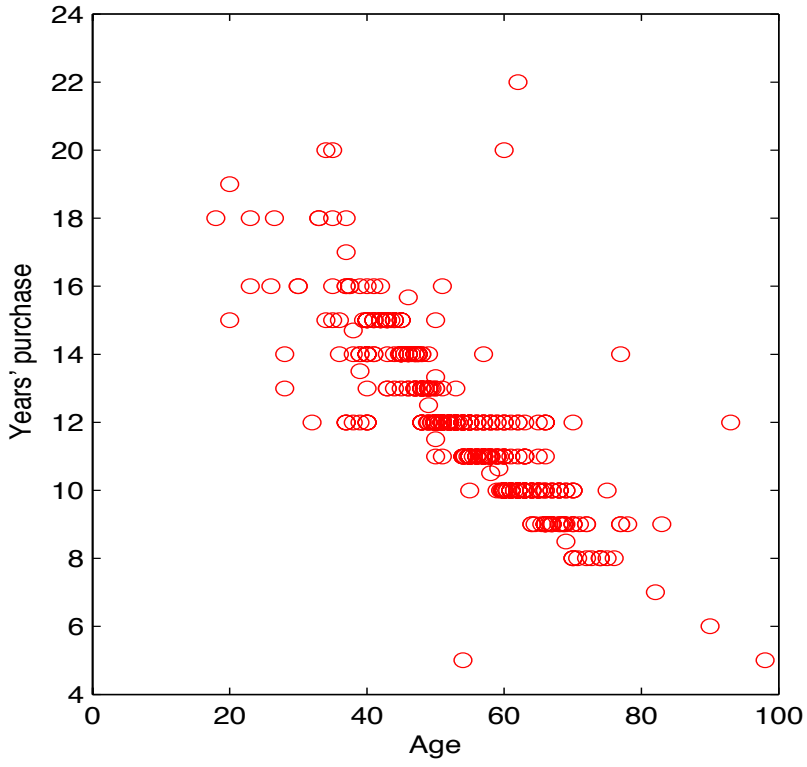
While Depauw (1999) p. 285 states that "price does not depend on the age of the lender", Fosseyeux (1912) p. 189 gives an age-price table found at the *Bibliothèque Nationale*[11]: unfortunately, this is only a one-page manuscript inserted in a volume of papers brought together much later; we have thus no hint where this paper comes from nor when it was effectively implemented. The only way to know what happened at the *Hôtel-Dieu* is to find direct evidence. The primary sources were neglected so far, as they are trick to use: on the one hand, the *Hôtel-Dieu*'s own notary recorded every sale of annuity and kept a copy of the contract (AN MC XXXIII), on the other hand, the board of the hospital examined every request for life annuities in the original *record of proceedings* (Archives AP-HP cote 1438). When the board authorized a transaction, one of the notary's clerks immediately drafted the contract so that the "donator" could sign it. In fact, both sources are necessary as no sale contracts mention the age of the annuitant before 1679 (and some still do not after), but the matching process is awkward: in 1667 for instance, out of 55 entries, only 3 ages-price associations were made. Sometimes, the proceedings of the board state an age-price pair, but never make it clear whether the transaction was eventually made. Even such *pricing*, which did not lead to a transaction, still reveal the *supply price* of annuities. Figure 1 summarises the total number of transactions for the 1650-1690 period (red line) together with a count of instances of

[11] Fosseyeux quotes "MSS Fr 11364 fol. 77"; the contemporary reference is MF 34302 fol. 477.

valuation (*i. e.* including those which were not followed by the issuance of a security) for some years.

From the 3,023 annuities sold by the *Hôtel Dieu* according to the *insinuations du Châtelet*, we collected more than 1,300 observations, from which 581 valid (age, price) pairs (represented by the bars on figure 1) were successfully double-checked. Observations were not selected on a purely random basis, as some files are damaged beyond repair, and some years appear more interesting: we selected especially 1665-1668 to determine the beginning of the implementation of a price table, then 1675 to 1677 because of the Franco-Dutch war, and 1687 as the last complete year without financial trouble. Years 1671 and 1684 were chosen randomly and added for comparison purpose, as well as the first half of 1674, and the second half of 1682. The resulting (age, price) pairs are plotted on figure 2.

Figure 2 (age, price[12]) pairs



It must be noted that some joint life annuities were sold during the 1660's but we neglected a thorough study since they were discontinued after a few dozen were sold. Now that we have the data, let us analyse them.

[12] Price in years' purchase

2. The pricing of *Hôtel-Dieu*'s annuities

Our data points to an age-price table, which does not seem *exact*. Spread can be explained as *charitable biases* (2.1.) as the data seem to converge toward a definite table (2.2.), very close to Deparcieux' results, computed almost a century later from data of the 1680's (2.3.)

2.1. Age-price table and charitable biases

The 581 (age, price) pairs provided by the database were plotted on figure 2. There seem to be "steps" in the figure, which constitute age-class eligible to a given price (in years purchase). The classes are somewhat blurred, though, because they partially overlap, although for each class there is a non-overlapping *core*. This core corresponds to the aforementioned table found by Fosseyeux at the *Bibliothèque Nationale* (MSS Fr 34302 fol. 477):

Table 1 life annuity prices per age class (in years purchase) From MF34302

	Hôtel-Dieu	Hôpital Général
30 years	20 y.p.	16 y.p.
35 years	17 y.p.	15 y.p.
38 years	16 y.p.	15 y.p.
40 years	15 y.p.	14 y.p.
45 years	14 y.p.	13 y.p.
48 years	13 y.p.	13 y.p.
50 years	12 y.p.	12 y.p.
55 years	11 y.p.	11 y.p.
60 years	10 y.p.	10 y.p.
65 years		9 y.p.
70 years		8 y.p.

It is worth noting that this document features *two* age-price tables: one for the *Hôtel-Dieu*, another one for the *Hôpital Général*, although we did not found any archival evidence of a large annuity trade corresponding to the latter institution. The two last "steps" in our database (age-classes 65-69 and 70+) nevertheless correspond to the table for the *Hôpital Général*, while for the 38-65 years annuitants, the data seems to follow the alleged *Hôtel-Dieu* table.

The data does not fit the table very precisely, but spread can be rationalized as the result of *charitable biases*. *Charitable bias I* arise when young people considering taking holy orders or training as priests were offered a discount: as an income is

required to enter a convent or religious institution, the devout administrators thus provided an incentive by offering reduced price. Disabled persons are a neighbouring case: they can not marry nor take holy orders because of their disability, hence the *Hôtel-Dieu* is better off by offering them a discounted annuity rather than accommodating them forever. The many examples at hand[13] show that the discount is variable; hence we cannot rationalize it fully. This *charitable bias I* nevertheless explains deviation to the left in figure 2 (see Appendix A for a representation).

Charitable bias II is symmetrical, it happens when (true) donators offered more than the required amount. This charity bias is especially noticeable among older fellows, who give all they have to the Hôtel-Dieu in exchange for annuities[14]. When we look at figure 2, there are obvious right 'distribution tails' to 12, 11, 10 and 9 years purchase above 50 years, which embody this *charitable bias II*. One must recall that even at this price, annuities were still a bargain in comparison with perpetuities, sold at 20 years purchase from 1665 on (during peacetime). The "charitable deeds" was then very attractive. Some donators, though, paid the full price of a perpetuity: this gives some (4) outliers which we eliminated for better statistical result. Appendix A offers a regression of observed price against the price table found by Fosseyeux: the result are significant, but the fit is poor before 1680.

Charitable biases might then explain some of the deviations from the table appearing in the MF34302, another reason is that the nature of the assets donated as well as the financial situation of the institution might influence the price[15]. Eventually, the selling price appear to be converging toward the theoretical table during the 1660's.

2.2. Time convergence…

There are some preliminary price tables appearing in the *record of proceedings* for 1665 and 1666, which do not match the (presumably) later MF 34302 table, as shown in table 2.

[13] Among dozens of examples: 20th of May 1667, Malachie Kelly, founder of the Irish college, funds a scholarship for François Burgois with a life annuity bought at only 15 years purchase while the young man is only 23 (this is a 25% discount). 14th January 1665, Marie Meusnier is awarded a discount (14 years purchase at age 28) because "she could not become religious while being disabled".

[14] See *e. g.* Françoise Jamet, 93 years, giving 2,000 livres on the 27th of March 1676 at 12 years purchase (while she might have obtained 8 y. p. or even less), Marie de Gaillard, 77, on 16th of september 1689, giving 700 livres at 14 y. p. (instead of 8), etc.

[15] This is especially true for the early years, when the board accepted donations of either house furniture or financial assets, especially *securitized loans* (*rentes sur particuliers*), which were commonly circulated, see Hoffman et al. (2000). Payment in kind became less frequent in the late 1670, although some discounts were granted "because the institution need money and not otherwise", especially during the Franco-Dutch War.

Table 2 earlier life annuity prices per age class (in years purchase) From the *records of the proceedings of the board* (RPB)

	RPB table 14th Aug.1665	RPB table 22nd Jan. 1666	HD MF 34302
30 years	-	16 y.p.	20 y.p.
35 years	-	16 y.p.	17 y.p.
38 years	-	16 y.p.	16 y.p.
40 years	-	16 y.p.	15 y.p.
45 years	-	16 y.p.	14 y.p.
48 years	-	16 y.p.	13 y.p.
50 years	12 y.p.	15 y.p.	12 y.p.
55 years	12 y.p.	14 y.p.	11 y.p.
60 years	12 y.p.	12 y.p.	10 y.p.
65 years	11 y.p. or 10 y.p.	-	9 y.p.
70 years	-	-	8 y.p.

As soon as April 1666, one transaction was made at 18 years' purchase, possibly indicating that the January table was already obsolete, but the MF 34302 does not feature an entry for 18 years' purchase. Looking at the distance between tween observed prices and price tables makes it clear that none of the tables were implemented in 1665 and that the MF 34302 was close to the effective distribution as soon as 1668. A Kolmogorov-Smirnov test of equality of distribution confirms that the distribution of selling prices is the same as the distribution of the MF34302 table from 1668 on: (table 3)

Table 3 mean sum of square distance to tables

Year	Mean sum of square distance, 1666 table	Number of observations	Mean sum of square distance, MF34302 table	Mean SSD MF34302 table, w/o outliers (number of obs)	Kolmogorov-Smirnov equality of distribution test at 5% (stat, p-value)
1665-7	5.62	71	4.63	4.34 (70)	✗ (0.2571, 0.020)
1668	7	18	0.72	0.72 (18)	✓ (0.111, 1.000)
1671	4.73	15	3.27	0.37 (11)	✓ (0.2727, 0.479)
1674-1679	136.0	149	5.5	1.97 (146)	✓ (0.0616, 0.927)
1680 and later	138.17	325	0.43	0.43 (325)	✓ (0.0402, 0.946)

While the MF34302 has a better fit than the 1666 table for every year or grouping of years, equality of distribution is only achieved if we leave aside charitable bias

outliers in 1671. After the Franco-Dutch war, the effective prices are very close to the table, but the war itself shows abnormal pricing behaviour in connection with financial distress (see note 15).

Table 3bis regression of actual annuities prices

t	table_ext	charitybiasI	charitybiasII	Constant	Adjusted R2
0	0.8928334	-1.461788	1.245522	1.25122	0.9002
1667	0.9498393	-1.321054	1.301382	0.5842409	0.9351
1670	0.949779	-1.30097	1.317797	0.5825639	0.9353
1673	0.9494559	-1.298788	1.234985	0.5848673	0.9419
1679	1.002469	-1.050647	1.302994	-.0284371*	0.9713
1679, no constant	1.000089	-1.048058	1.299154	n/a	n/a

All variables significant at 1‰ except * not significant

regress years_purchase table_ext charitybiasI charitybiasII if year>t

Eventually, it could be asserted that the effective pricing of *Hôtel-Dieu* followed the table since 1668, although there were significant deviations attributable to charitable bias or cyclical troubles, which were greatly reduced after 1680. How does this price table compare to contemporary prices?

2.3. … to Deparcieux

Before the Hôtel-Dieu sold annuities, only one age-price tables was known to exist: the 'table of Ulpian'. It was not used to compute the value of life annuities but the value of usufruct on real estate (in connection with the Roman inheritance law, which granted freedom of destination for only ¼ of one's wealth, the *quarta falcidia*). By comparison, early modern annuities prices were much flatter than the table of Ulpian: neither de Witt nor Hudde reached 20 years' purchase. In order to compare these tables with the *Hôtel-Dieu* pricing scheme, we computed how much de Witt's procedure would have given at later ages (as de Witt's table only give one valuation for 6 years of age).

Table 4 comparison of life annuity prices per age class (in years purchase)

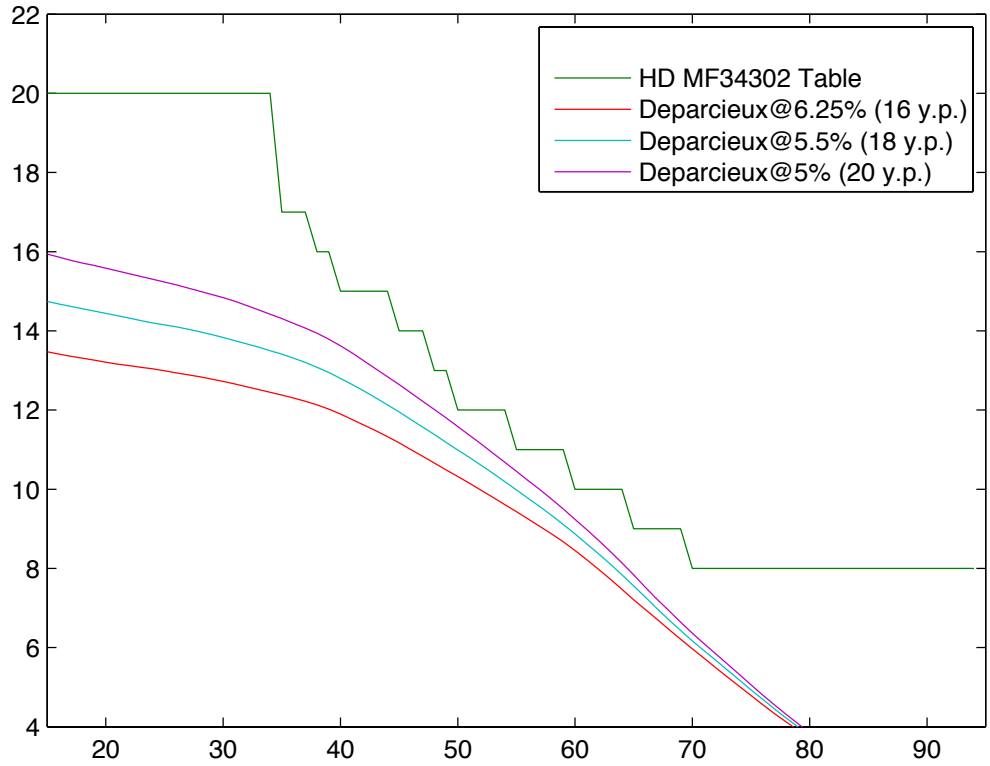
	Table of Ulpian ca. 220 AD	De Witt 1671 (generalization)	Hudde 1672	HD MF 34302
30 years	22 y.p.	12.2 y.p.	9 y.p.	20 y.p.
35 years	20 y.p.	11.4 y.p.	9 y.p.	17 y.p.
38 years	20 y.p.	10.9 y.p.	9 y.p.	16 y.p.
40 years	19 y.p.	10.5 y.p.	8.5 y.p.	15 y.p.
45 years	14 y.p.	9.6 y.p.	8 y.p.	14 y.p.
48 years	11 y.p.	9.1 y.p.	8 y.p.	13 y.p.
50 years	9 y.p.	8.7 y.p.	7.5 y.p.	12 y.p.
55 years	7 y.p.	7.8 y.p.	6.75 y.p.	11 y.p.
60 years	5 y.p.	6.8 y.p.	6 y.p.	10 y.p.
65 years	5 y.p.	5.8 y.p.	5 y.p.	9 y.p.
70 years	5 y.p.	4.8 y.p.	4 y.p.	8 y.p.

The comparison between the *Hôtel-Dieu* and contemporary tables (Table 4) brings two main conclusions:

- overall, the *Hôtel-Dieu* table commends considerably higher prices than the contemporary tables. A simple arithmetic mean of prices shows a 85% premium over the Hudde table and 54% over Johann de Witt;
- while they might have controlled adverse selection, these high prices were not a deterrent: the *Hôtel-Dieu* really sold annuities at these high prices, especially for people above 40.

Charging a higher price for annuities than other contemporary tables does not guarantee the sustainability of the life annuities selling business, though. In order to assess sustainability, we should compare those prices with the average life expectancy of annuitants. Alter and Riley (1986) surveyed all existing mortality tables of the time and find Deparcieux' (1746) to give the longest life expectancy; longest even than contemporary reconstruction by the Cole-Demeny model for a life expectancy at birth of 40 years (p. 21-23). The reason for this is that Deparcieux statistics were computed from the annuitants of the first *tontine*, issued in 1689. As only people who feel in good health buy life annuities, Deparcieux' data take into account the adverse selection problem, which other early demographers could not address. Moreover, the anthropological characteristics of both population (from the first *tontine* and the *Hôtel-Dieu*) should be as close as possible (same middle to upper class urban population of France in the 1660-1680). Figures 3 compares the pricing by *Hôtel-Dieu* with prices taken from Deparcieux (1746).

Figure 3 comparison of prices for life annuities Hôtel-Dieu extended table with Deparcieux at various interest rates



The (so far) unexpected result is that the *Hôtel-Dieu* sold life annuities at a price, which is even higher than the figures computed by Deparcieux for 18 (5,56%) or 20 (5%) years' purchase. These rates were the *taux du roy* respectively until 1665 and after. Hoffman *et al.* (2000) have shown that these *taux du roy* were not only *maximum* interest rate on private loans: all assets had the same yield to maturity, without an idiosyncratic allowance for risk (with the exception of *rentes* in time of distress), hence their title "priceless markets". On average, for years 15 to 90, the annuities sold by the *Hôtel-Dieu* were priced 34% above the pure premium price derived from Deparcieux' table, they were thus sustainable. Nonetheless, the *hospital des incurables* (a twin hospital run by the same board) defaulted the quarterly payment of annuities in June 1689, and so did the *Hôtel-Dieu* three months later, in October. As we have shown the annuities to be correctly priced, the causes of this bankruptcy must be found somewhere else.

3. Forensic evidence on bankruptcy

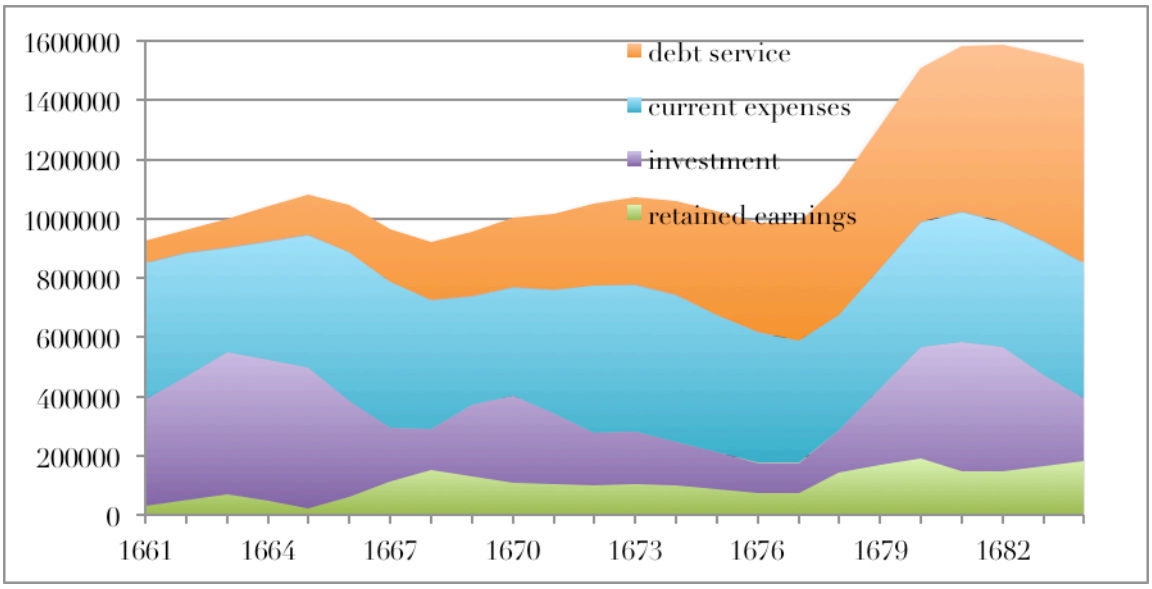
In order to find the causes of bankruptcy, we analysed the accounting data, as provided by the *Mémoires et instructions concernant le revenu temporel de l'Hôtel-Dieu*

de Paris (AN K1024). This source gives some detail about the expenses from 1660 to 1684. It appears then that the most likely cause is the undercapitalization of annuities (3.1.). Some other factors might have played a role, if not in the ineluctable bankruptcy, at least in the timing of the crisis (3.2.).

3.1. A Ponzi scheme?

The *mémoires et instructions* provide data grouped in irregular 2-3 years periods from 1660 to 1684. We can infer a rough distribution of expenses, distinguishing *debt service* (on loans and annuities), (other) *current expenses*, *retained earnings* and *investment*. Figure 4 shows the evolution, with rising debt service and diminishing investment (detailed figures in appendix D).

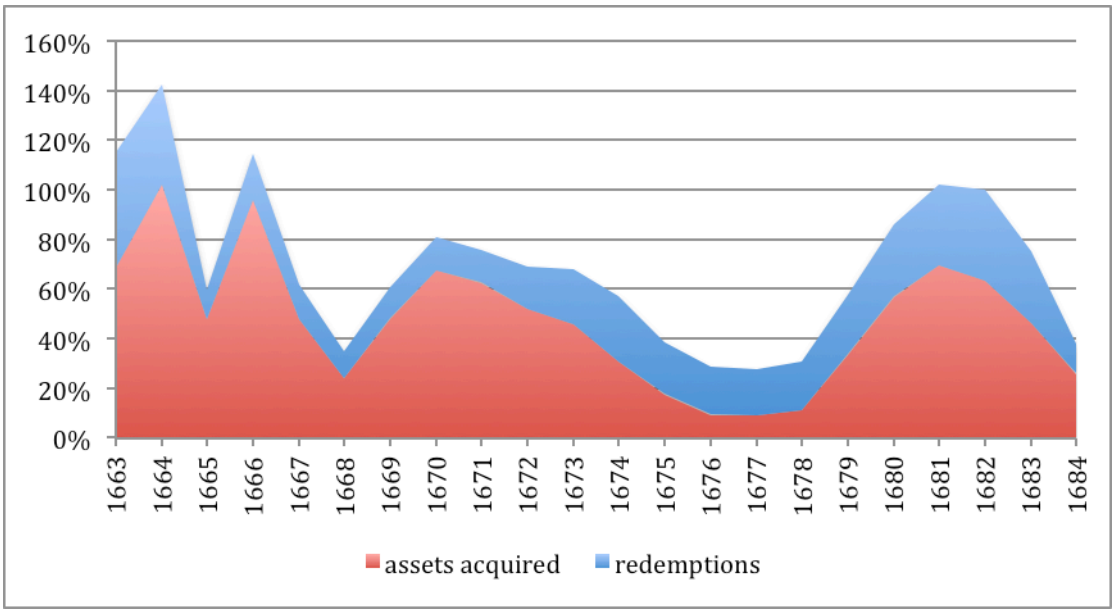
Figure 4 expenses of the Hôtel-Dieu in *livre tournois* 1661-1683



Investment is the heart of the subsequent problem: in order to secure future payments, the amount collected when selling annuities should be invested into revenue-producing assets. The time offered few opportunities, though: real estate was generally considered locked in, and financial assets were hardly available in quantity, particularly in time where the Crown was not borrowing (which was the case before the Franco-Dutch War, hence until 1673). Nevertheless, the *Chambre de Justice* of 1661-1665 offered an opportunity: it was set up to judge the wrongdoings of Fouquet and his creatures, and caused many financiers to sell their real estate in order to invest their (fishy) money into assets protected from seizure… which was the case of life annuities (while perpetuities were considered real estate under custom of Paris, life annuities were considered "movable" property, hence not amenable to seizure). The *Hôtel-Dieu* thus experienced both an influx of money (the sale of annuities brought more than 600,000 livres in turnover for the year 1665) and opportunities to invest: in the week of 13th of May 1665 alone, the board bought 10 houses in Paris according to the *proceedings*!

A more complete examination of the figures shows that less than 45% of the amount gathered by the sale of annuities between 1662 and 1684 was invested in revenue producing assets (Figure 5). While the ratio is 63% on average for 1662-1673, it suddenly drops with the Franco-Dutch war, down to 9% in 1676. The average for the next decade is 35%. The lack of available assets to invest cannot be alleged here, as the War provided excellent investment opportunities (in *rentes sur l'Hôtel de Ville*), as section 4 will show. Hence, it seems quite clear that the proceeds of the sale of annuities were not sufficiently invested into revenue-producing assets that could have secured future payments. A definite and rising fraction of the proceeds fuelled current expenses.

Figure 5 investment in proportion of annuities sales



Although informative about the overall trend, this approach is not entirely conclusive since the data does not cover the whole period to 1690 on the one hand, while on the other hand it does not take into account the planned future expenses but the actual revenue, which might include some donations. A more correct approach would be to check every year that the additional capitalization reserves exceed the expected future expenses measured by $\sum_{t=1}^{n_y} s_t \times p(a_t)$, where n_y is the number of contracts on year y, s_t the amount of annuities acquired by contract t and $p(a_t)$ the price per *livre* of annuity depending on the age a_t of the contractor, as given by the Deparcieux table at the current legal interest rate. Since the dataset is not (and, as shown in section 1., it is likely never to be) exhaustive, we must provide an approximation of the capitalization reserves needed to guarantee payment of future annuities. We could, for instance, consider the minimum and maximum s_t and $p(a_t)$: table 5 shows for the years with enough observations the average amount of annuities bought by donators and the mean price following Deparcieux table. It must be understood that the Deparcieux table provides the mathematical expectation of life, hence the price given by the table is the absolute minimum, with no provision for fluctuation of mortality or increase in longevity. From this

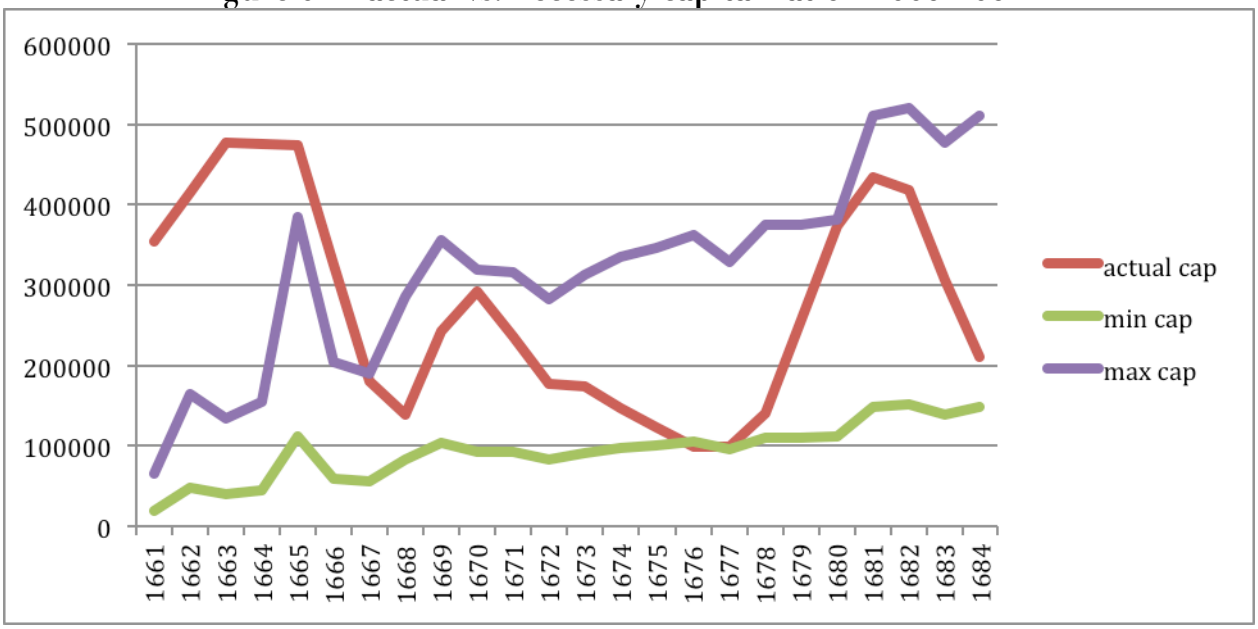
table, we can infer two couples of minimum and maximum $(\bar{s}_t, \bar{p}(a_t))$, which will be compared to the actual flow of capitalization reserves. The result is plotted on figure 6.

Table 5 mean annuity and mean Deparcieux expected price for selected years

Year	1665	1668	1671	1674	1675	1676	1677	1679	1682	1684	1687	1689
$\bar{s}_t$	428.4474	340	274.8182	226.6111	351.7205	388.9367	507.5726	256.3936	300.0381	323.2979	326.0215	316.2214
$\bar{p}(a_t)$	4.232813	4.737368	5.870667	5.456875	5.072927	6.405938	6.20375	6.022692	6.494222	5.988333	5.585565	6.389535

Figure 6 has the same profile as figure 5 and confirms that the investment level was not entirely satisfactory: even the most favourable assumptions of minimum required capital are above the actual investment during the War of Holland. Taking into account the average of *min* and *max* would have made the *Hôtel-Dieu* losing money 10 years out of 24. Although we rely here on guesstimates, it is likely that the level of investment was not consistent with the expected payments. Hence the annuities sales, although it was done at a fair price, was undercapitalized. Recalling McHugh's 2007 p. 79 words "the evidence for how the HD overcame its deficit are scanty…" we might think we have documented the means to overcome the deficit: "appeal[ing] for more charity", to quote McHugh. In fact, the board sold annuities in order to fund growing expenses, initiating a soft, protracted Ponzi scheme. The next question is then: why did bankruptcy happen in 1689?

Figure 6 actual vs. necessary capitalization 1660-1684



3.2. Efficient causes

Right after the Franco-Dutch War, the *Hôtel-Dieu* suffered a permanent fall in its financial revenue. While more than 75,000 livres were supposed to come every year from the *rentes sur l'Hôtel de ville de Paris*, this amount was reduced for various reasons. On the one hand, the perpetuities issued during the War at a very profitable 14 years' purchase (see Béguin 2012), were converted to 20 years' purchase; this is a 30% reduction on the 20,000 livres the *Hôtel-Dieu* bought during the War of Holland. On the other hand, the "old" perpetuities issued before 1640 and still reported at their face value in the "truthful statement" of 1663 were supposed from 1665 to be "converted"; this was done in 1679 on a 1:6 basis, leading to a loss of almost 40,000 livres of yearly revenue. Both reductions amounted to almost 8% of the yearly *expense*.

Then, it is generally agreed (Marczewski 1961) that the French economy experienced a downturn in 1686 with an en ensuing liquidity squeeze. The number of annuities sold in 1687 was lower than 1686 (-2%) and much lower in 1688 (-28%). Although we do not have any accounting information for these years (as the *mémoires et instructions* were interrupted since 1684), there is no reason to think that the expenses could have been contained, as the debt burden kept rising at accelerated pace, and the Nine years war would have surely brought in many indigent seeking relief and shelter (as the winter of 1662 did before). With diminishing income and rising expenses, the fragile *Hôtel-Dieu* could not withstand more than a year of war. A former near-bankruptcy episode has been premonitory: the turnover of annuities sales were down by 21% in 1676 over 1675, with a stable year 1677. On the 30th of June 1677, the *proceedings of the board* feature a statement that "Sir Lecomte knows that the *Hôtel-Dieu* needs money, and the *Incurables* is ready to give 15.000…" What happened? Thank to the help provided by its twin brother *Incurables*, the *Hôtel-Dieu* made it through, but the king was made aware of the problem, and inclined to shutting down the annuities window once the war was over (proceedings, 28th april 1679). It seems that Colbert or other very high protector obtained some delay, so that the annuities sales continued. In 1690, however, the Crown closed the annuity window without much hesitation. Taxes (on wine and public shows) were created to fund the *Hôtel-Dieu* and guarantee the payment of annuities, but the sale of life contingent contracts was over, together with the associated Ponzi scheme…

4. Macroeconomic implications

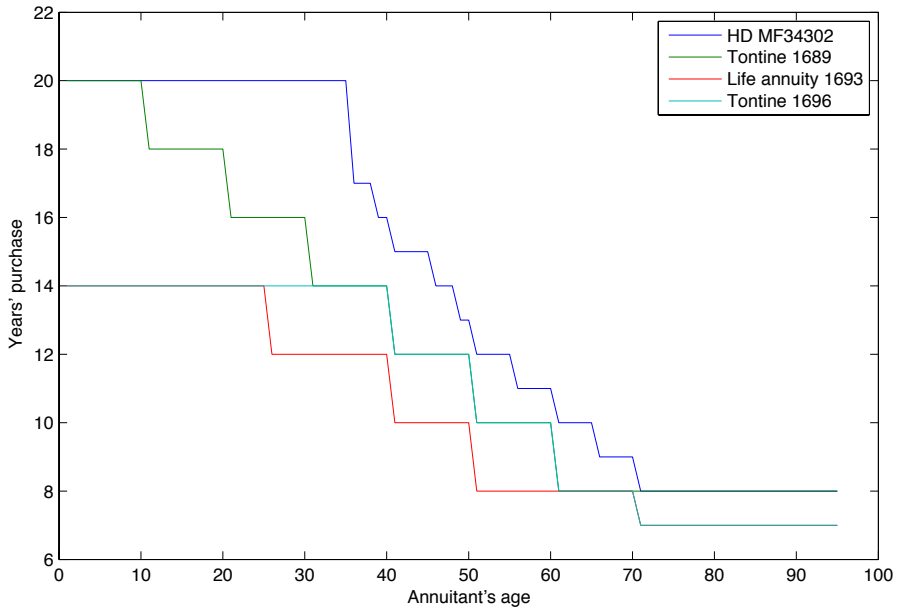
At the very moment when the *Hôtel-Dieu* experienced Ponszi-induced bankruptcy, the French monarchy began issuing life-contingent annuities to fund the Nine Years' War: in 1689 a first batch of *tontines* (Gallais-Hamonno and Berton 2008), before regular life annuities were introduced in 1693. The synchronicity with the failure of the *Hôtel-Dieu* raises questions: did the Crown borrow at a more

sustainable price? (4.1.) In which case, the more attractive competition might have been a competitive threat. Or is it that the King borrowed at more favourable conditions for the borrower, in which case the failure of the *Hôtel-Dieu* would have been a clear sign of unsustainability of the state debt? Eventually, we shall ask whether there was any competition between various financial assets (4. 2.).

4.1. Did the Crown borrow at a more sustainable price?

As the edict of January 1690 forbade for hospitals to issue life annuities, because this was not sustainable, one can expect the life-contingent annuities issued by the *Hôtel de Ville* from 1689 on to be offered at higher prices. Looking at the price table of the *rentes*, they appear to be priced lower than their *Hôtel-Dieu* counterpart, as the figure 7 shows:

Figure 7 pricing tables of French life-contingent contracts 1689-1696

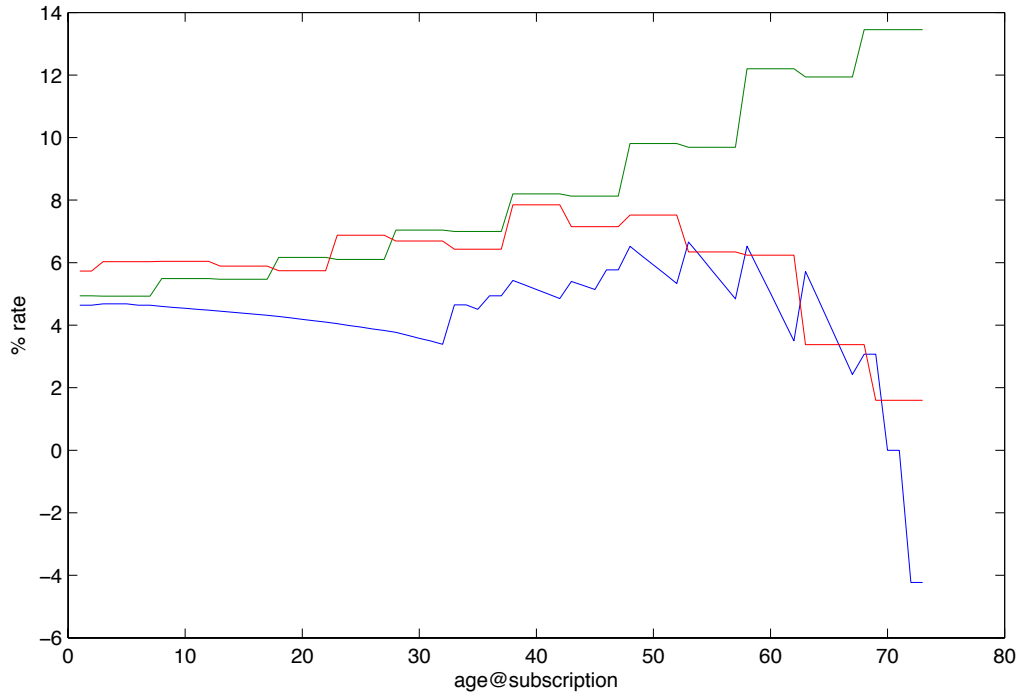


After 1693, it is worth noting that the *tontine* of 1696 was even more expensive than the first one in 1689. Starting in 1702, life annuities were offered at a flat 10 years' purchase rate, hence close to 8% yield to maturity when invested on the head of 6-year child. The rising servicing cost of life-contingent annuities seem to confirm Katia Béguin (2012) proof that the borrowing rate has been rising along Louis XIV's reign, as a consequence of protracted wars against ever more numerous and powerful enemies.

While years' purchase are enough to understand that the Crown was borrowing at unsustainable rates during the Nine years' war, this information does not immediately provide the borrower with an estimated cost of credit, nor the lender with his expected yield. Gallais-Hamonno and Berton computed the expected yield according to age, and we did the same for the *Hôtel-Dieu* (assuming the same

mortality as for the annuitants of the *Tontine*), next graphics sums up the corresponding information (figure 8). The yield of all four instruments is very close for younger lenders, it rises steadily with age for the *Tontine*: this was probably done to incentivize older prospects, and disarm the aforementioned tendency of speculators to buy annuities on the head of children already noticed by de Witt. The result is a very high expected return on the tontine for elderly: more than 13% at 75 years. But, as the appendix E shows, the age-structure of the annuitants is less concentrated than for the *Hôtel-Dieu*, which offered lower yields to maturity at older ages: overall, *it does not seem that the yield to maturity was correctly guessed by the contemporaries*.

Figure 8 expected yield to maturity on contingent assets



Next, the *cost of credit*, which is significant for the borrower, is computed relatively to the age-structure of the lenders. We do have this structure for both the *Tontine* and the *Hôtel-Dieu* (see appendix E), but not for the life annuity of 1693 (which indeed sold very poorly). The next table summarizes the mean expected returns and costs for the age structure of the *Tontine* (and in parenthesis for the age-structure of the *Hôtel-Dieu*):

Table 6 comparison of prices of life-contingent securities

	Hôtel-Dieu	*Tontine* 1689	Life annuity 1693
Average years' purchase	14.4 (11.52)	12.06 (10.03)	10.4 (8.55)
Average nominal yield	6.94% (8.68%)	8.29% (9.97%)	9.62% (11.70%)
Average expected YTM	5.13% (5.03%)	8.62% (10.02%)	6,74% (6.43%)
Average borrowing cost per 1£	0.52 (0.41)	3.12 (2.90)	1.33 (0.96)
Present value @5% of	0.44	2.59	1.19

borrowing cost per 1£	(0.35)	(2.48)	(0.88)

The nominal yield is simply the inverse of the years' purchase figure. While the average yield is higher for the 1693 life annuity than for the 1689 *Tontine*, the ranking of expected yield to maturity (computed using Deparcieux' mortality table) is inverted. The reason here is simply that the *Tontine* features reversionary payments: in each class, when one annuitant dies, his future income will be shared among the survivors until the last member of the class dies. The borrower thus pays far longer than with a usual life annuity. Now, the average borrowing cost, which is the flat sum of expected future payments above the amount paid by the annuitant, is *far* higher with the *Tontine*. If these sums are discounted at 5%, then the spread is somewhat reduced, but the *Tontine* remains by far the more expensive way to borrow… Before the French monarchy resorted to flat-rate life annuities at 10% in 1702.

These returns were *promised*, and Katia Béguin (2012) has shown that these French pseudo-sovereign securities were all but riskless: very often, the arrears were not paid to owners of the common, especially during the *Fronde*, they were reduced after the *Chambre de Justice* of 1661, and again after 1710. It shall then be asked how much the public was sensitive to these high interest rates: we are led to test for crowding out between the Hôtel-Dieu annuities and the *rentes sur l'Hôtel de ville*.

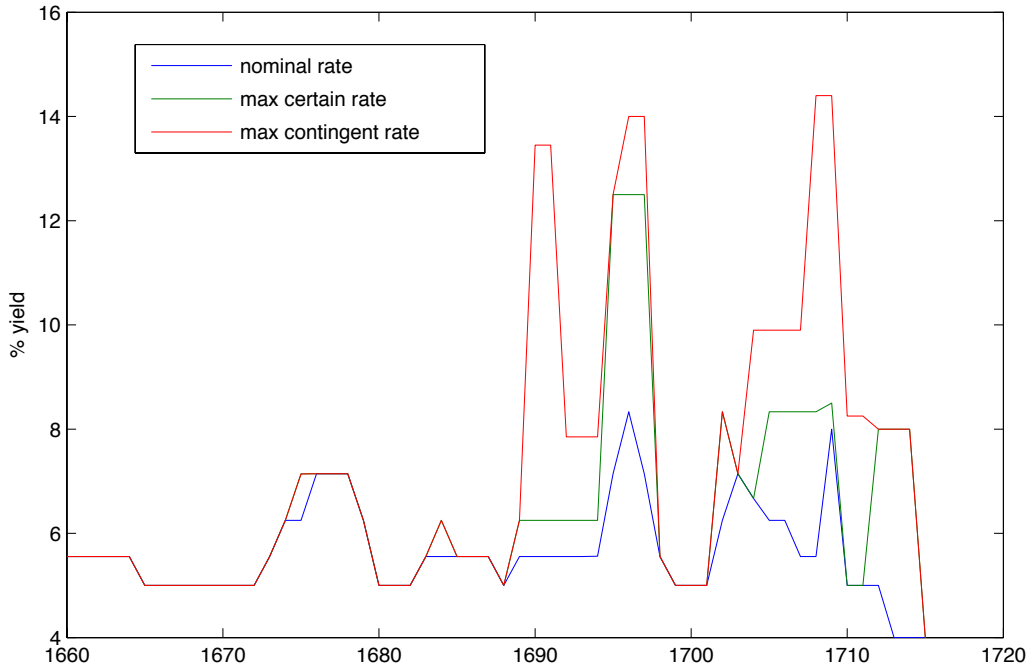
4.2. Competition between financial assets? new data sets

While it is beyond our scope to give a complete account of Béguin (2012), it shall be recalled that her book made at least two breakthroughs, since it contains new extensive new time series on interest rates and debt issuances.

On interest rates, the true figures were usually concealed for two different reasons: the enemy could notice that strong capital demand denotes the weakness of the kingdom, while inside the country, and raising the interest rate on new issuances would debase already issued securities. The ban on usury was supposed to benefit both the warmonger hawks, as the borrowing rates appeared steady hence the cost of war was apparently under control, and the devout doves, as steady rate protected the market value of assets. To achieve this apparent convergence, yield to maturity was dissimulated by various tricks, mainly issuance premiums (through *blank forms* in the 1650-1670 and then *anticonversions*) and life-contingent features (after 1689), see annex for an overview. It seems that the French monarchy has been experimenting to "squeeze out" every single drop of liquid assets. Graph 7 shows the whole time series for Louis XIV active reign: the picture looks more complex than the classic account of Homer and Sylla[16] (2005) p.128.

[16] While the statement by these authors that "here is little evidence of an organized money market in France in the seventeenth century" has been adressed by Hoffman et al. 2000, the figures they quoted (5% interest rate for 1665-1688 and after 1697 while in between "some *rentes* […] between 1688 and 1697 which again paid 8⅓%") is made more precise by Beguin (2012).

Figure 9 nominal rates on *rentes*, yield to maturity and expected YTM

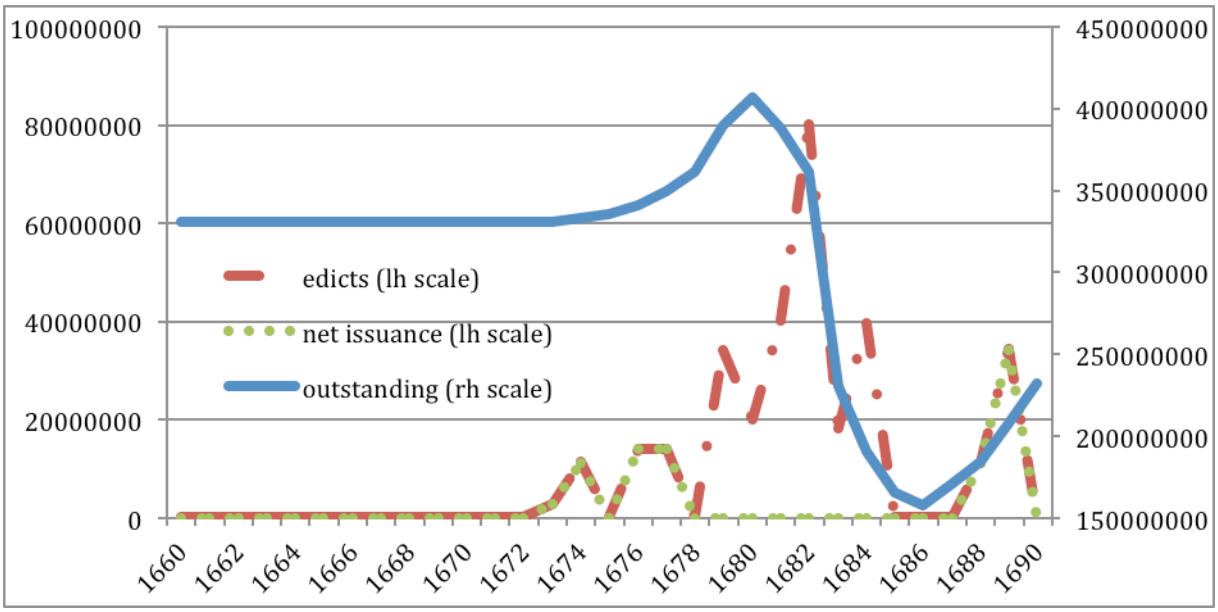


The rates reported here are *maximum* yields, either the expected yields of the best age class for contingent securities, or more generally the yield for *lenders with connections* (insiders), which enabled the effective payment of arrears (coupons), while most common annuitants (outsiders) might experience reduced payments (*i. e.* partial default). The spikes on the graph obviously correspond to war episodes: the Franco-Dutch war (1672-1678), then the Nine years' war (1688-1697), eventually the War of the Spanish succession (1701-1714). The high return on contingent securities for 1689 is exactly the return on the aforementioned *Tontine*, but some later issuances (such as the *rentes de rachat de capitation* in 1709) offered an even higher yield. These new data make it possible to test for crowding out effect, but a thorough inquiry should also take into account the *volumes* of debt issued.

There are then many obstacles to the measurement of either the amount of debt outstanding or the issuances, as the State relied on various instruments and the remaining accounting documents are scarce. Among instruments, the *rentes sur l'Hôtel de ville* were close to perpetual bonds, but there also existed a *floating debt* made of *bills*; the state could also profit from selling *offices*, which were remunerated by wages (called *gages*), not coupon payment. Fortunately for our research, bills were mostly issued later in the reign, and, as the offices, they are not perfect substitutes for *rentes* (since they are not perpetual; in the case of offices, the

wages were conditional on some work, which could not be done, for instance, by women or children, hence they could not provide them with an income). The *rentes sur l'Hôtel de ville* then seem the main debt instrument to be compared with the annuities sold by the *Hôtel-Dieu*. The amount of *rentes* issued had been counted by Moulin (1998), who noted every issuance authorized by an edict of the King; but Béguin (2012) has shown that some edicts were not followed by an actual issuance, and some issuances were used to consolidate previously issued debt at better conditions, especially when wars ended. Hence the list in Béguin (2012) clearly distinguishes between new debt issuance, consolidation and debt reduction by debasement of previously issued securities which happens during the period under review since Colbert decided in 1665 to *officially* reduce the arrears served on *rentes* (which were already reduced since the *Fronde* in the 1640's), but the face value of *rentes* was reduced only[17] after the end of the war in 1680 through conversion to new rentes. However complex the situation is, Béguin (2012) provides us with sound data on *gross* debt issuance between 1660 and 1690, as well as on *net* new issuances, which were not designed to absorb previous instruments. Figure 8 plots the resulting data:

Figure 10 amount outstanding and issuances of *rentes sur l'Hôtel de Ville*



While the amount outstanding rises with new issuances at the beginning of the Franco-Dutch war, a progressive default starting in 1680 then reduces the amount outstanding despite continuing issuance of new securities.

These datasets provided by Béguin (2012) allow us to test whether the perpetuities sold by the *Hôtel de Ville* competed with the annuities sold by the *Hôtel Dieu*.

[17] It might seem desperate to *command* that the market value of assets stay at a given level when the income of the same asset is cut; we recall here that anti-usury legislation prohibited to buy assets below par. See Turgot 1770 for a discussion of the actuality of the law.

4.3. Competition between financial assets? testing a simple model

For the Hôtel-Dieu, we do not have the amount of perpetuities issued every year, and it is likely that we will never have such data since some documents were damaged by a flood (the whole year 1679 for instance, is inaccessible). Nevertheless, we have the yearly *count* of the annuity contract subscribed, which appeared in figure 1. This is the variable we try to explain. The demand for such contracts may depend on a constant, a trend, the wealth created during the relevant period, and there might be some *crowding out* due to the issuance of perpetuities, especially if the amount issued is large or the interest rate is high. Hence our basic model would be:

$$(0)\ \text{contracts\_count}_t = \beta_1 + \beta_2 t + \beta_3 \ln(\text{rate}^{\text{RHVP}}{}_t) + \beta_4 \ln(\text{GPP}_t) + \beta_5 \ln(\text{debt issuance}) + \varepsilon_t$$

Where GPP denotes the *gross physical product*, as computed by Marczewski (1961). We expect the coefficient for interest rate and debt issuance to be negative, while GPP should be positive. We tried various specifications for the interest rate (nominal, ytm and expected ytm) and for the debt issuance (gross and gross issuance + debt redemption since the net issuance is sometimes negative). An appendix gives the detail of the regression, but the next table gives the quintessential results:

Table 7 regression results

Model	*(3.3.)*	*(3.3. bis)*	*(5.1.)*	*(5.2.)*	*(5.3.)*
Rate type	contingent	contingent	nominal	YTM	contingent
Number of observations	30	30	30	30	30
F-Stat	43.41	62.15	25.06	24.85	26.64
R^2	0.8336	0.8215	0.8393	0.8381	0.8473
Adjusted R^2	0.8144	0.8083	0.8058	0.8044	0.8155
β_1 / const.	-32124**	-18221**	-65925**	-63198**	-41849
β_2 / *trend*	-3.34		-10.38**	-9.77**	-5.01*
β_3 / rate	-7.33**	-9,24**	-11.65	-10.36	-6.11*
β_4 / GPP	1529**	869,5**	3135**	3005**	1991**
β_5 / issuance.			-0.944	-0.868	-0.76
β_6 / redempt			-0.768	-0.712	-0.26

* significant at 5% ** significant at 1%

Adding explicative variables do not necessarily provide better result, since issuance figures are hardly significant, whether we consider gross or net data. The best estimate is eventually given by a very simple model (3.3. bis) with only three

variables: the constant, a wealth effect (GPP) and an interest-rate effect. More generally, the regressions make it clear that the effect of wealth on annuity subscription is strong: a 1% growth of the annual product would likely bring 15 more contracts. Even if the issuance of debt does not have any significant crowding out effect, the maximum interest rate on newly issued *rentes sur l'hôtel de ville* has a definite impact: model 3.3. bis shows that the impact of a one-point increase of the interest rate on the *rentes sur l'hôtel de ville* would bring 9 less contracts to the Hôtel-Dieu, that is around 9% of an average year.

The crowding out effect is then effective, and relies especially on the maximum yield achieved on contingent annuities. This is consistent with the content of the *proceedings of the board*, which show many examples of young people alleging they "could get a better return" from some other borrower: for instance, on the 8th of February 1679, a 33 years old asks for "10 or 12 years' purchase" as 14 years' purchase perpetuities are available from the *Hôtel de Ville*, which is less expensive than the price in the regular *Hôtel-Dieu* table (18 years' purchase). As a result, young people were quite rare in the age-structure of the annuitants, which are more concentrated in later ages (see appendix E), since the price of life annuities was more attractive for them than what they could have obtained from the *Hôtel de Ville*. In this respect, crowding out might have been a somewhat bilateral effect among borrowing institutions: in peace time, low years' purchase attracted elder people to the *Hôtel-Dieu*, but during wars, rising interest rates progressively deterred everyone to invest with this institution, starting with the younger. This bilateral crowding out effect is likely to have provided the Crown with one more reason (the main one being the foreseeable consequence of the Ponzi scheme) to terminate the supply of life annuities by the *Hôtel-Dieu*.

*

Conclusion

The *Hôtel-Dieu* was not just a hospital in early modern Paris, it was the showcase of the rising elite since the 1630's: devout, urban, well into the king's businesses. To keep on funding the modernization of the old hospital and developing medicalization in face growing social pressure, the administrators of the *Hôtel-Dieu* decided in 1662 to emphasize the sale of life annuities. We have shown that, from 1668 on, the annuities sold by the *Hôtel-Dieu* were priced, on average (for years 15 to 90), 34% above the pure premium price derived from Deparcieux' table: they were thus sustainable *if only they had been rightly* used to buy revenue producing assets. Unfortunately, buying an annuity from the institution was framed as a good deed: the buyer was called a *donator*, contributing to the hospital expenses. The corresponding debt had not then to be funded and the administrators relied on a growing number of annuitants to pay for the earlier ones. Overall, the operation was soft Ponzi scheme: a very poor demonstration of expert financial management, eventually.

The story of *Hôtel-Dieu*'s bankruptcy has wider consequences as it provides us with a benchmark of the state borrowing capacity. Until the beginning of the Nine Years' War, the French sovereign experienced high but sustainable borrowing rates. By the time the hospital went bankrupt, the *rentes sur l'Hôtel de Ville de Paris* were offered in life-contigent flavour much cheaper for the buyer than the annuities sold by the *Hôtel-Dieu*… and deliberately unsustainable for the borrower, as the war was not a profitable investment (the overall return computed by François Velde 2008 was 0.7%). A crowding out effect between contingent securities seem to have existed, relying mainly on the rough comparison of price, stated in years' purchase. Even if the buyers did not correctly guess the yield to maturity, the Crown's financiers knew the scheme was unsustainable. The monarchy only succeeded in hiding the true borrowing rate, which was supposedly strategic information not to be disclosed in time of war.

This inquiry into French finance of the *Grand Siècle* can be interpreted as a confirmation of what we know: neither actuarial science nor holistic thinking existed by that time, and the French king was trying to abuse his subjects with delusional borrowing schemes followed by financial repression; at the same time, the Dutch Republic enjoyed de Witt's enlightened view on annuities and Britain was on the verge of a financial revolution. The twin failure of the *Hôtel-Dieu* and of the French Exchequer demonstrates the state of financial illiteracy of the French... Or, of the time: the present reader might think that Graunt (or Petty, following Le Bras 2000), Huygens and Halley had a clear understanding of the valuation of lives: it shall be recalled that de Witt's study was met with a hanging rope; and a century later in the Duchy of Calenberg, whose sovereign was the King of England himself, the widow fund he sponsored gone bankrupt on the same kind of Ponzi scheme (Rosenhaft 2006) as the *Hôtel-Dieu*. This might deserve another study.

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Annex nominal rate manipulation techniques

1. *Blank* forms

This is a pre-filled form leaving only the names of the beneficiary and the intermediary. Such forms enabled *syndicated issuance* (by specialists) in the 1650s, an alternative to the previous solution of *forced loans*. The specialists bought bonds on wholesale, then sold them through the blank form, which could then be registered by a notary. The blank form opened many opportunities for fraud: successive sales can be performed before the form is brought to the notary, meanwhile the annuity is more or less a bearer share, which can freely circulate. The true cost of borrowing, as well as the margin of the intermediaries are concealed, in contradiction with the anti-usury laws. Katia Beguin undertook a major investigation to clarify the use of this instrument.

2. Issuance premia

Offering free coupons has long been a marketing trick when the annuities were not sought after, but the issuance premia climbed during the Franco-Dutch War: the first modest issuances in 1673-4, were not entirely subscribed although the interest rate was raised to 5.5% (18 years' purchase) and 6.25% (16 years' purchase). In December 1674, the price of annuities was lowered to 14 years' purchase (7.14%), while the contracts still mentioned 16 years' purchase, which were to be refunded to the lender after the war. The premium could also take the form of a partial payment in (debased) treasury bills, which reduced the actually paid capital. This solution was used repeatedly during the War of Spanish Succession, when the *billets de monnoye* have been multiplied, suffering heavy discount from their face value, and were accepted into increasing proportions with a fraction of species for annuity purchases. It was an incentive for paper-holders to get rid of it, both during the war and in the aftermath consolidation of debt.

Issuance premia distort both the yield to maturity and amount outstanding to an extent that it is impossible to clarify in the current state of research. Concealment seems to have been organized (no record of the amounts actually received by the Exchequer, no accounting of the blank forms, official recognition of biased notarial acts), so that we can never get the truth. Only the crudest tricks can be reported without doubt.

3. Anti-conversions

The anti-conversions were implemented during the Nine Years' War (1688-1697) and reactivated during the War of Spanish Succession. The principle of conversions performed throughout Western Europe to reduce the interest on annuities, is simply inverted: the annuitants could get a coupon rate rise in exchange for more money. A concrete example will help: the owner of a 100 pounds-annuity at 20 years' purchase paid 2,000 pounds for 100 pounds of yearly income. When the interest rate is raised at 18 years' purchase, the former debt owner can buy as much new debt as they have old debt, the overall debt quantity being computed at the new price. Hence, the owner of 2,000 pounds worth of

capital for a 100 pounds per year annuity, shall now add 1,600 pounds to get 100 pounds more per year, so that overall they invested 3,600 for a yearly income of 200 (18 years' purchase).

In December of 1694, the Crown offered anti-conversion at 14 years' purchase, that is, owner of 20 years' purchase annuities could invest at 8 years' purchase, so that 20 + 8 = 28 / 2 = 14 years' purchase (100 pounds of annuity bought for 2,000 plus 100 pounds bought for 800 = 200 pounds of annuity bought for 2,800).

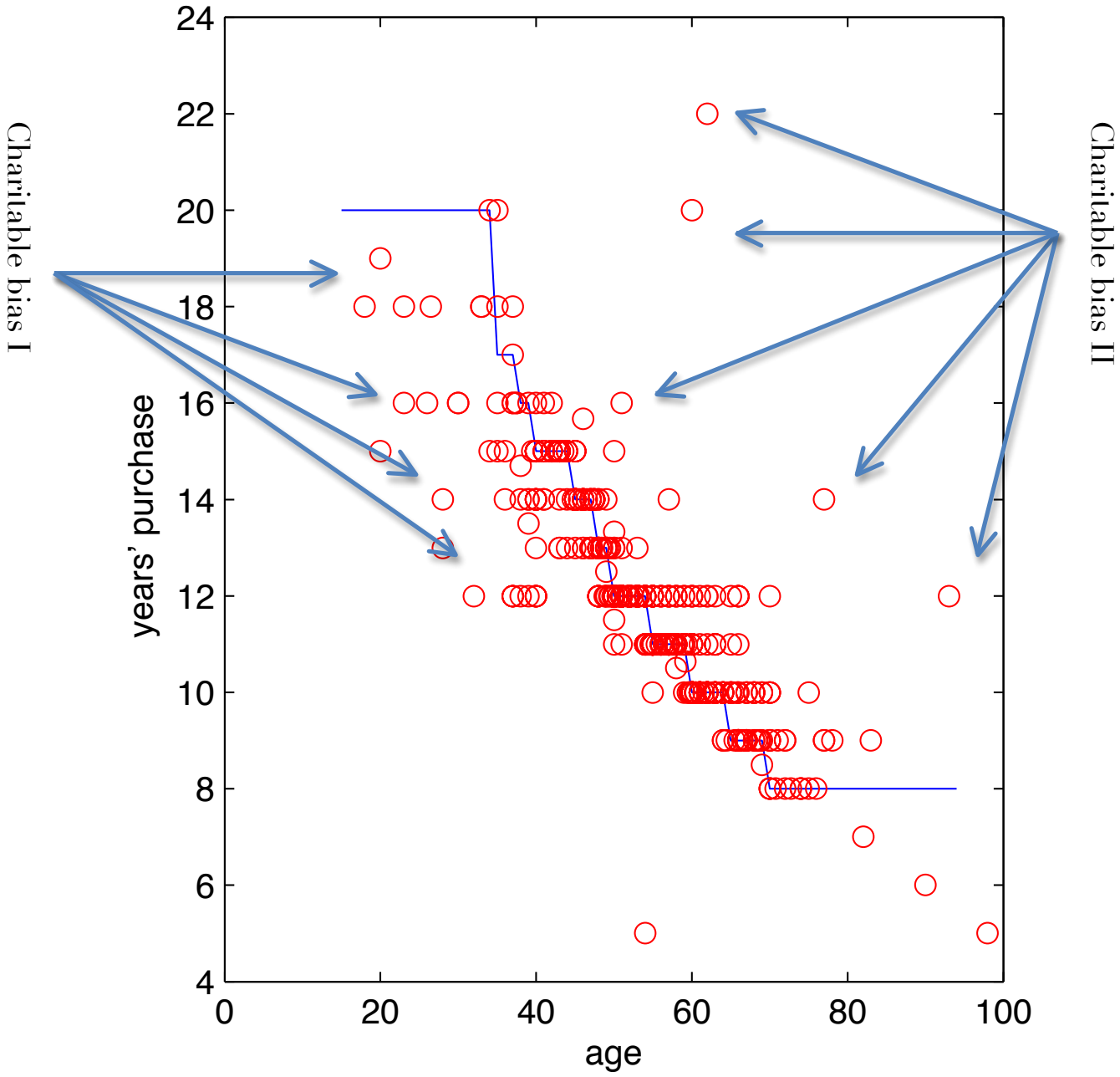
Anti-conversions are then responsible for a spike in Figure 7 ; it is dubious, though, that all instances have been found so far.

4. Contingent annuities

The common practice in the late Middle Ages Germany, was to offer life annuities at half the years' purchase of perpetual annuity (see e. g. Daston [1988], Gilomen [2003] Hébrard [2004] Munro [2003] Poitras [2000] van Schaik [2003]). Flat (i. e. non-independent) price obviously entails a risk of adverse selection: de Witt [1671] is so far the first to mention how buyers of annuities selected children who had just proved their health by resisting childhood diseases. Such choice maximises the expected return. Hup [2011] has established a database of about a thousand contracts to test whether adverse selection happened in real life: he showed that buyers for their own account were on average twenty years older than the heads who commanded someone else's pension. This means that there was in that time two very different approaches to annuity buying: one uses the instrument to guarantee an income for life, the other targets an abnormally high yield and bets on longevity of a head. In the sample of Hup, the first behavior represents only 20% of the subscribed volume.

Can we extend the reasoning Hup to France? We know pretty well the age structure of the first *tontine* (through Deparcieux), and of the Hotel-Dieu (from our database): appendix E draws some conclusions from the comparison. In the current state of research, we have no idea of the population of annuitants from flate-rate annuities, which Hup studied, and which were issued in France after 1702.

Appendix A
Plotting the Charitable biases



Appendix B

Fitting the data with the MF34302 Table

Regressing annuity price (in years purchase) on the HD table of MF34302 'extended' with HG value for 65+ years

Number of obs	581				
F(1, 579)	= 2282.05				
Prob > F	= 0.0000				
R-squared	= 0.7976				
Adj R-squared	= 0.7973				
Root MSE	= .94923				
years_purc~e	Coef.	Std. Err. t	P>t	[95% Conf.	Interval]
table_ext2	.7262623	.0152031 47.77	0.000	.6964024	.7561221
_cons	3.216251	.1861527 17.28	0.000	2.850634	3.581868

Appendix C

Illustrating time convergence

Regressing for years 1680+

Number of obs	328				
F(1, 326)	= 2991.34				
Prob > F	= 0.0000				
R-squared	= 0.9017				
Adj R-squared	= 0.9014				
Root MSE	= .62846				
years_purchase	Coef.	Std. Err. t	P>t	[95% Conf.	Interval]
table_ext2	.916061	.0167491 54.69	0.000	.883111	.9490109
_cons	1.055664	.1954139 5.40	0.000	.6712324	1.440095

Regressing for years 1674-1679 (Franco-Dutch War[18]) (without outliers)

Number of obs	146				
F(1, 144)	= 703.31				
Prob > F	= 0.0000				
R-squared	= 0.8301				
Adj R-squared	= 0.8289				
Root MSE	= 1.0124				
years_purc~e	Coef.	Std. Err. t	P>t	[95% Conf.	Interval]
table_ext2	.7384668	.0278457 26.52	0.000	.6834277	.7935059
_cons	3.011844	.3448637 8.73	0.000	2.330195	3.693493

[18] Strictly speaking, the Franco-Dutch war lasted from 1672 to 1678. When we look at the interest rate served on rentes sur l'Hôtel de Ville de Paris (see section 4), the relevant period of high rates is 1674-1679.

Regressing for years before 1674

Number of obs	107				
F(1, 105)	= 145.42				
Prob > F	= 0.0000				
R-squared	= 0.5807				
Adj R-squared	= 0.5767				
Root MSE	= .98508				
years_purc~e	Coef.	Std. Err. t	P>t	[95% Conf.	Interval]
table_ext2	.4019301	.0333302 12.06	0.000	.3358425	.4680177
_cons	7.581628	.4564209 16.61	0.000	6.676629	8.486626

Appendix D

"Truthful statement" of income and expenses 1663-1684

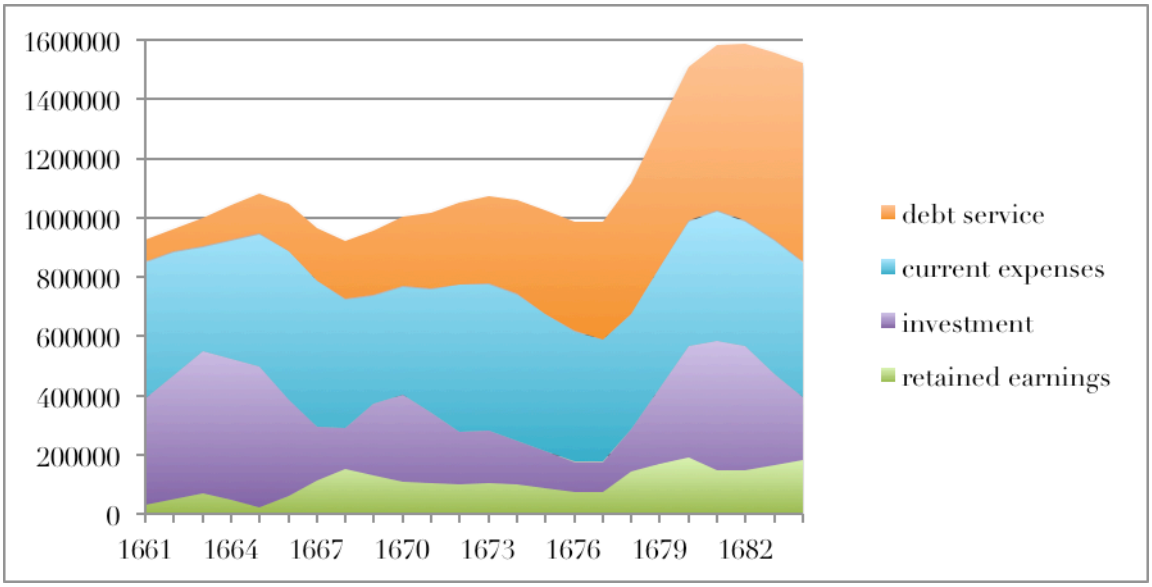
The *mémoires et instructions* provide data grouped in irregular 2-3 years periods[19]. This raw data was recompiled into modern categories and smoothed with a 3-year mobile average.

	retained earnings	investment	current expenses	debt service
1661	34710	354763	461709	73653
1662	53887	416347	414058	77621
1663	73064	477931	350549	97447
1664	48709	476288	398123	117273
1665	24355	474645	445697	137099
1666	62536	326778	497519	156925
1667	115380	180553	491633	176751
1668	155067	138819	429825	196578
1669	132219	243310	363769	216404
1670	112034	292430	363073	236230
1671	105004	237060	418298	256056
1672	102671	178368	493083	275882
1673	107368	175047	492817	295708
1674	100619	147601	492946	315534
1675	89173	123476	462402	346473
1676	77728	99351	438519	370752
1677	77728	99351	411635	397636
1678	144982	140956	388706	439306
1679	169713	257965	402965	479888
1680	194444	374974	418153	519540
1681	151129	434660	436691	558262
1682	150338	418942	419761	596352
1683	167666	307510	447527	633653
1684	185786	211797	452319	672767

The graph provided in the text sums up these data.

[19] To be precise, these periods are: 1660-1661, 1662-1664, 1665-1666, 1667-1668, 1669-1670, 1671-1672, 1673-1674, 1675-1678, 1679, 1680-1681, 1682-1683 and 1684 alone.

Debt of the Paris Hôtel-Dieu 1660-1690

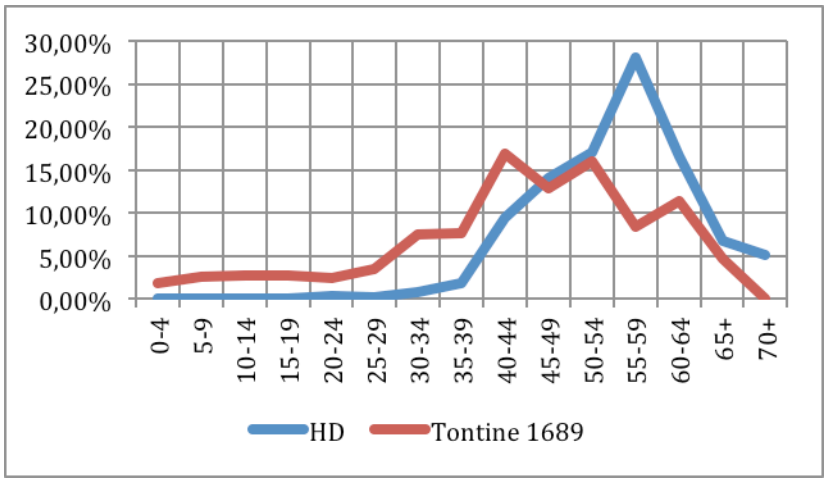


Appendix E
Age-Structure of *Hôtel-Dieu* and *Tontine* annuitants

The age-structure of annuitants is summed up in the following table:

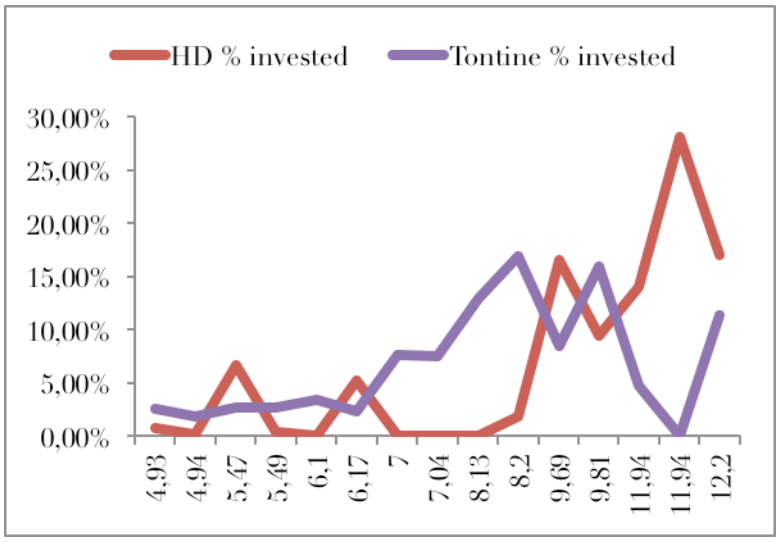
Class	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Age	0-4	5-9	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65+	70+
HD	0,00%	0,00%	0,00%	0,00%	0,37%	0,14%	0,75%	1,87%	9,36%	14,01%	17,02%	28,06%	16,56%	6,68%	5,17%
Tontine 1689	1,74%	2,53%	2,63%	2,60%	2,31%	3,35%	7,44%	7,58%	16,83%	12,81%	15,88%	8,35%	11,32%	4,64%	0,00%

Which can be supplemented by a plot:



It is then instantly visible that the tontine annuitants are less concentrated in the 50 to 64 years range, and more equally spread among the possible ages.

Gallais-Hamonno and Berton 2008 p. 57 noticed that the ages distribution is in no way determined by the yields, as if investors were not attracted by returns. The next figure provides an insight supplemented by a table:



While it might seem irrational to look for lesser returns, investment in a life annuity is tricky: even when it is possible to invest on somebody else's head, as is the case here, asymmetric information might be a deterrent for uncertainty-averse investors, hence a "personal bias" (in the same sense as *home bias*). Hence, the difference between the *Hôtel-Dieu* and the *Tontine* population is that the HD annuitants are mostly looking for a retirement pension-like income, while some *Tontine* annuitants are looking for an investment opportunity, if not a gamble (on a child's head).

Table shares invested in different age-classes as a function of expected YTM

HD		Tontine	
YTM	% invested	**YTM**	% invested
3,58	0,75%	4,93	2,53%
3,94	0,14%	4,94	1,74%
4,07	6,68%	5,47	2,60%
4,19	0,37%	5,49	2,63%
4,38	0,00%	6,1	3,35%
4,49	5,17%	6,17	2,31%
4,54	0,00%	7	7,58%
4,64	0,00%	7,04	7,44%
4,66	0,00%	8,13	12,81%
4,74	1,87%	8,2	16,83%
5,02	16,56%	9,69	8,35%
5,14	9,36%	9,81	15,88%
5,47	14,01%	11,94	4,64%
5,75	28,06%	11,94	0,00%
5,93	17,02%	12,2	11,32%

A picture gives a quick overall view.

Appendix F
Test of crowding-out effect

Annuity demand model

$$(0)\ \text{contracts\_count}_t = \beta_1 + \beta_2 t + \beta_3 \ln(\text{rate}^{\text{RHVP}}{}_t) + \beta_4 \ln(\text{GPP}_t) + \beta_5 \ln(\text{debt issuance}) + \varepsilon_t$$

Where GPP measures the *gross physical product* (computed by Marczewski [1961]), RHVP means *rentes sur l'Hôtel de ville de Paris*, the quasi-sovereign debt securities. As there are different means to measure the rates and issuance, we performed the following regression

$$(1)\qquad \text{contracts\_count}_t = \beta_1 + \beta_2 t + \varepsilon_t$$

Simple model for control purpose.

$$(2)\ \text{contracts\_count}_t = \beta_1 + \beta_2 t + \beta_3 \ln(\text{rate}^{\text{RHVP}}{}_t) + \varepsilon_t$$

Where $\text{rate}^{\text{RHVP}}$ can be alternatively the apparent rate (2.1.), the maximum certain rate (2.2.) as computed by Béguin (2012) or the maximum contingent rate (2.3.).

$$(3)\ \text{contracts\_count}_t = \beta_1 + \beta_2 t + \beta_3 \ln(\text{rate}^{\text{RHVP}}{}_t) + \beta_4 \ln(\text{GPP}_t) + \varepsilon_t$$

Here again we review 3 submodels (3.1) with apparent rate, (3.2.) with max certain rate and (3.3.) with max contingent rate.

$$(4)\ \text{contracts\_count}_t = \beta_1 + \beta_2 t + \beta_3 \ln(\text{rate}^{\text{RHVP}}{}_t) + \beta_4 \ln(\text{GPP}_t) + \beta_5 \ln(\text{gross issuance}) + \varepsilon_t$$

The model is tested with gross debt issuance as recorded, for instance, by Moulin (1998). 3 submodels with the usual indices.

$$(5)\ \text{contracts\_count}_t = \beta_1 + \beta_2 t + \beta_3 \ln(\text{rate}^{\text{RHVP}}{}_t) + \beta_4 \ln(\text{GPP}_t) + \beta_5 \ln(\text{net issuance}) + \varepsilon_t$$

As the 'net issuance' series would feature negative figures, the model must be replaced with

$$(5.b)\ \text{contracts\_count}_t = \beta_1 + \beta_2 t + \beta_3 \ln(\text{rate}^{\text{RHVP}}{}_t) + \beta_4 \ln(\text{GPP}_t) + \beta_5 \ln(\text{issuance}) + \beta_5 \ln(\text{redemption}) + \varepsilon_t$$

Where redemption is the yearly volume of debt redemption, as computed by Béguin (2012). 3 submodels with the usual indices.

The results appear in the following pages.

Model 1.

Number of obs	30
F(1, 28)	= 39.94
Prob > F	= 0.0000
R-squared	= 0.5879
Adj R-squared	= 0.5732
Root MSE	= 26.064

contracts_count	Coef.	Std. Err. t	P>t	[95% Conf.	Interval]
t	3.474527	.5497769 6.32	0.000	2.34836	4.600694
_cons	45.61149	9.760153 4.67	0.000	25.61873	65.60426

Model 2. 1.

Number of obs	30
F(2, 27)	= 19.74
Prob > F	= 0.0000
R-squared	= 0.5938
Adj R-squared	= 0.5637
Root MSE	= 26.35

contracts_count	Coef.	Std. Err. t	P>t	[95% Conf.	Interval]
t	3.523294	.5612166 6.28	0.000	2.371774	4.674814
apparent_rate	-4.692943	7.471588 -0.63	0.535	-20.02337	10.63749
_cons	70.96245	41.54969 1.71	0.099	-14.29047	156.2154

Model 2.2.

Number of obs	30
F(2, 27)	= 20.49
Prob > F	= 0.0000
R-squared	= 0.6028
Adj R-squared	= 0.5734
Root MSE	= 26.057

contracts_count	Coef.	Std. Err. t	P>t	[95% Conf.	Interval]
t	3.597252	.5629868 6.39	0.000	2.442098	4.752405
certain_rate	-6.834078	6.786367 -1.01	0.323	-20.75855	7.090397
_cons	82.24435	37.66307 2.18	0.038	4.96614	159.5226

Model 2.3.

Number of obs	30
F(2, 27)	= 45.32
Prob > F	= 0.0000
R-squared	= 0.7505
Adj R-squared	= 0.7335
Root MSE	= 19.808

contract_c~t	Coef.	Std. Err. t	P>t	[95% Conf.	Interval]
t	4.207589	.4467578 9.42	0.000	3.290918	5.12426
contingent_rate	-11.38129	2.45576 -4.63	0.000	-16.4201	-6.342491
_cons	101.1559	14.09459 7.18	0.000	72.23616	130.0756

Model 3.1.

Number of obs	30
F(3, 26)	= 36.26
Prob > F	= 0.0000
R-squared	= 0.8071
Adj R-squared	= 0.7848
Root MSE	= 18.505

contract_count	Coef.	Std. Err. T	P>t	[95% Conf.	Interval]
t	-8.123755	2.207754 -3.68	0.001	-12.66186	-3.585652
apparent_rate	-10.58199	5.36076 -1.97	0.059	-21.60119	.4372079
GPP	2456.659	458.1913 5.36	0.000	1514.833	3398.485
_cons	-51634.76	9643.676 -5.35	0.000	-71457.62	-31811.9

Model 3.2.

Number of obs	30
F(3, 26)	= 37.08
Prob > F	= 0.0000
R-squared	= 0.8105
Adj R-squared	= 0.7887
Root MSE	= 18.339

contract_c~t	Coef.	Std. Err. T	P>t	[95% Conf.	Interval]
t	-7.748053	2.161556 -3.58	0.001	-12.19119	-3.304911
certain_rate	-10.14702	4.816475 -2.11	0.045	-20.04742	-.2466091
GPP	2392.988	448.1968 5.34	0.000	1471.707	3314.27
_cons	-50296.63	9435.79 -5.33	0.000	-69692.17	-30901.08

Model 3.3.

Number of obs	30
F(3, 26)	= 43.41
Prob > F	= 0.0000
R-squared	= 0.8336
Adj R-squared	= 0.8144
Root MSE	= 17.187

contract_count	Coef.	Std. Err. t	P>t	[95% Conf.	Interval]
t	-3.341575	2.434964 -1.37	0.182	-8.346714	1.663564
contingent_rate	-7.329132	2.491079 -2.94	0.007	-12.44962	-2.208646
GPP	1529.225	486.9568 3.14	0.004	528.2707	2530.179
_cons	-32124.28	10261.67 -3.13	0.004	-53217.46	-11031.11

The interest rate is not significant at the 1% level in 3.1. and 3.2. In 3.3., *t* is not significant, we performed a regression without *t* as…

Model 3.3. bis

Number of obs	30
F(2, 27)	= 62.15
Prob > F	= 0.0000
R-squared	= 0.8215
Adj R-squared	= 0.8083
Root MSE	= 17.466

contract_count	Coef.	Std. Err. t	P>t	[95% Conf.	Interval]
contingent_rate	-9.242151	2.098022 -4.41	0.000	-13.54694	-4.937366
GPP	869.482	78.7817 11.04	0.000	707.8353	1031.129
_cons	-18221.83	1661.795 -10.97	0.000	-21631.55	-14812.11

Model 4.1.

Number of obs	30
F(4, 25)	= 31.19
Prob > F	= 0.0000
R-squared	= 0.8331
Adj R-squared	= 0.8064
Root MSE	= 17.555

contract_count	Coef.	Std. Err. t	P>t	[95% Conf.	Interval]
t	-8.624574	2.109734 -4.09	0.000	-12.96965	-4.279495
apparent_rate	-8.400703	5.204369 -1.61	0.119	-19.1193	2.317897
GPP	2699.087	451.7086 5.98	0.000	1768.776	3629.398
issuance	-1.084267	.5497066 -1.97	0.060	-2.216409	.0478747
_cons	-56754.22	9509.584 -5.97	0.000	-76339.58	-37168.87

Model 4.2.

Number of obs	30
F(4, 25)	= 31.10
Prob > F	= 0.0000
R-squared	= 0.8327
Adj R-squared	= 0.8059
Root MSE	= 17.576

contract_count	Coef.	Std. Err. t	P>t	[95% Conf.	Interval]
t	-8.271776	2.091565 -3.95	0.001	-12.57944	-3.964118
certain_rate	-7.666971	4.81341 -1.59	0.124	-17.58037	2.246434
GPP	2627.17	448.4453 5.86	0.000	1703.58	3550.761
issuance	-1.019688	.5608067 -1.82	0.081	-2.174691	.1353152
_cons	-55243.81	9443.711 -5.85	0.000	-74693.49	-35794.12

Model 4.3.

Number of obs	30				
F(4, 25)	= 34.42				
Prob > F	= 0.0000				
R-squared	= 0.8463				
Adj R-squared	= 0.8218				
Root MSE	= 16.843				
contract_count	Coef.	Std. Err. t	P>t	[95% Conf.	Interval]
t	-4.616576	2.545169 -1.81	0.082	-9.85845	.6252989
Contingent_rate	-5.8908	2.637626 -2.23	0.035	-11.32309	-.4585079
GPP	1882.4	536.5408 3.51	0.002	777.3739	2987.427
issuance	-.8018605	.5568457 -1.44	0.162	-1.948706	.3449846
_cons	-39570.78	11307.83 -3.50	0.002	-62859.7	-16281.86

4.1. and 4.2. are not satisfactory since there are still significativity issues.

In 4.3. neither *t* nor *gross issuance* are significant, hence the model breaks down to 3.3. bis.

Model 5.1.

Number of obs	30
F(5, 24)	= 25.06
Prob > F	= 0.0000
R-squared	= 0.8393
Adj R-squared	= 0.8058
Root MSE	= 17.581

contract_count	Coef.	Std. Err. t	P>t	[95% Conf.	Interval]
t	-10.37982	2.792759 -3.72	0.001	-16.14379	-4.615852
apparent_rate	-11.6502	6.212736 -1.88	0.073	-24.47266	1.172257
GPP	3135.293	640.8027 4.89	0.000	1812.741	4457.844
Issuance	-.9440588	.5695438 -1.66	0.110	-2.119539	.2314219
Redemption	-.7683351	.7993828 -0.96	0.346	-2.41818	.8815098
_cons	-65925.28	13481.53 -4.89	0.000	-93749.8	-38100.77

Model 5.2.

Number of obs	30
F(5, 24)	= 24.85
Prob > F	= 0.0000
R-squared	= 0.8381
Adj R-squared	= 0.8044
Root MSE	= 17.644

contract_count	Coef.	Std. Err. t	P>t	[95% Conf.	Interval]
t	-9.770912	2.680612 -3.65	0.001	-15.30342	-4.238402
certain_rate	-10.35789	5.682933 -1.82	0.081	-22.08689	1.371108
GPP	3005.452	616.029 4.88	0.000	1734.031	4276.873
Issuance	-.8684973	.5875136 -1.48	0.152	-2.081066	.3440711
redemption	-.7120675	.7915864 -0.90	0.377	-2.345822	.9216866
_cons	-63197.92	12963.69 -4.87	0.000	-89953.65	-36442.18

Model 5.3.

Number of obs	30
F(5, 24)	= 26.64
Prob > F	= 0.0000
R-squared	= 0.8473
Adj R-squared	= 0.8155
Root MSE	= 17.136

contract_count	Coef.	Std. Err. t	P>t	[95% Conf.	Interval]
t	-5.015004	2.783145 -1.80	0.084	-10.75913	.7291249
Contingent_rate	-6.112645	2.74296 -2.23	0.035	-11.77384	-.4514542
GPP	1990.579	612.1257 3.25	0.003	727.2136	3253.944
issuance	-.7612756	.5759822 -1.32	0.199	-1.950044	.4274932
redemption	-.260949	.6681452 -0.39	0.700	-1.639933	1.118035
_cons	-41848.67	12898.48 -3.24	0.003	-68469.82	-15227.53

Adding redemption information does not improve the performance of any model. Hence model 3.3. bis seems the best fit, but it is worth notice that elasticity of contract count to the interest rates is rather robust among regression specifications.

Overall, a one-point increase in the rate served on the Rentes sur l'Hôtel de Ville de Paris results in around 10 less annuity contracts signed at the Hôtel-Dieu.

Data mining (i. e. dropping one variable or another) to test the significance of issuance figures does not bring any positive result.